A DESCRIPTION AND ANALYSIS

OF

A REFLECTIVE STUDY OF THREE SCIENCE UNITS

by

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APPRECIATION

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>THE PROBLEM</td>
<td>5</td>
</tr>
<tr>
<td>I DESCRIPTION AND ANALYSIS OF PROCEDURE</td>
<td>7</td>
</tr>
<tr>
<td>A unit on electricity</td>
<td>7</td>
</tr>
<tr>
<td>Summary and suggestions</td>
<td>72</td>
</tr>
<tr>
<td>II A UNIT ON ELEMENTARY CHEMISTRY</td>
<td>79</td>
</tr>
<tr>
<td>Analysis of unit</td>
<td>100</td>
</tr>
<tr>
<td>Summary and suggestions</td>
<td>103</td>
</tr>
<tr>
<td>III A UNIT ON FIRE CONTROL</td>
<td>110</td>
</tr>
<tr>
<td>Analysis of unit</td>
<td>117</td>
</tr>
<tr>
<td>Summary and suggestions</td>
<td>120</td>
</tr>
<tr>
<td>IV EVALUATION OF THE STUDY</td>
<td>124</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>133</td>
</tr>
</tbody>
</table>
"Education is a process of modifying behavior." By accepting this definition, the teacher of any subject has the responsibility of determining how that subject may modify the behavior of the boys and girls who study it. Other problems raised by this statement are: In what direction shall behavior be modified? What is the most effective method of teaching? To answer any of these questions, the type of society into which our program of education is to be fitted must be considered. It is logical to assume that behavior should be modified so that an individual is better qualified to live in the desired form of social organization.

In this country we still believe that democracy is the way of life that we desire. Democracy has been defined as a "form of social organization which provides equality of opportunity for participation in a growing area of interests mutually shared."¹ This definition places a dual responsibility on education in a democracy. It assumes that we have enlightened citizens who not only have a competent, ever-increasing knowledge of their world, but also are capable of directing their own welfare. It is the task of the school to increase the child's knowledge of his world

¹ Bruce, Wm., "Principles of Democratic Education." Prentice-Hall. 1939.
while training him to learn by himself—to think reflectively.\textsuperscript{1} If citizens are to make their own decisions in matters of general welfare, they should be capable of doing independent thinking.

The method used to bring about these modifications of behavior should be a method that challenges the pupil to think about matters of vital interest. To quote John Dewey: "Permanently successful methods depend for their efficiency upon the fact that they go back to the type of situation which causes reflection out of school in ordinary life. They give the pupil something to do, not something to learn; and the doing is of such a nature as to demand thinking, or the intentional noting of connections; learning naturally results."\textsuperscript{2}

The situation should suggest something to do which is new and problematic. It should be one where there is some doubt or perplexity as to a course of action. A way out of the difficulty is sought and thinking begins. The thinking employed when one does not know just what to do is reflection-level thinking. To promote this type of thinking the material in a subject should be organized on the problem


\textsuperscript{2} Dewey, John, "Democracy and Education." Macmillan. 1916.
Science, perhaps more than any other school subject, raises problems that are of genuine interest to children. Science functions as a way of living, as a mode of interpreting the world in which we live. A child's questions are about the things in his world. Science provides an opportunity to answer these important questions. It helps him to see things or situations in relation to other things. He acquires meanings rather than information. Facts are acquired not as so much material to be memorized but as data needed in chasing down the solution to an enigma. Science gives the child a method of solving problems analogous to the type of thinking that should be applied to problems of living.

Many science units are still organized about collections of facts or scientific principles developed in a deductive manner. Science is thought of as organized knowledge rather than as a method of acquiring knowledge. Students become so conscious of learning that real learning does not take place. If a science unit is properly taught, it

is an excellent opportunity of training pupils to become better thinkers for the generalizations of science are themselves the product of reflective thinking.¹

THE PROBLEM

The purpose of this study is to describe and analyze the procedure employed in attempting to promote a reflective study of three science units.

The three units, "Electricity," "Elementary Chemistry," and "Fire Control," were taught to a group of sixth grade pupils in a town of about 15,000 inhabitants. There were thirty-three pupils in the group.

A day-by-day record of classroom procedure was kept and is presented in the description of the units. The material of the units is based on similar units in the science series, "Discovering Our World." The pupils, however, did not have access to this textbook. Other reference books were used and reading was motivated by the desire to find information which might help to solve problems growing out of the unit.

Each unit attempts to follow the general pattern of a reflective study which is: 1


1) Recognizing a genuine problem in the situation.
2) Recalling information and experiences that may suggest solutions to the problem.
3) Searching for new facts and making observations needed to deal with the problem.
(4) Testing the suggestions in the light of the new data.

(5) Arriving at a conclusion.

Each lesson in a unit is analyzed to see if it has the essential elements of a reflective study. The summary and suggestions at the close of the unit make comparisons and corrections in the procedure. In the analysis of the unit a three-way comparison is made. The actual procedure is contrasted with the textbook presentation, and then is criticized on the basis of how it should have been presented in order to promote reflective thinking.
CHAPTER I

DESCRIPTION AND ANALYSIS OF PROCEDURE USED IN A UNIT ON ELECTRICITY

Lesson 1.

At the beginning of the period, I told the class that I had been reading about a very bad wind and snow storm in the eastern part of the United States. I asked them if they thought that storms cause any more damage and destruction today than they did one hundred years ago. Charles did not think that they do because "people didn't use to have as good houses as we have now and then they didn't have the snow plows to clear the roads." Jacqueline thought that they do more damage today because there are more things to be blown down. James said that older people thought that wind storms used to be worse than they are now.

As there seemed to be a difference of opinion, I asked the class what damage storms used to do that might not be done today. James recalled stories of houses being picked up by wind, of people being carried away, and of large trees being torn from the ground. Junior was disgusted with James's answer because cyclones still do things like that. A number of the group agreed with Junior, but no one could think of any other differences.

I then asked, "What often happens today when there is
a bad storm?"

There were several responses to this question. Trees blown down and streets blocked. Lights go off. Roofs blown off. Electricity goes off and clocks and refrigerators stop.

"Doesn't every electric thing stop working when the electricity goes off during a storm?" asked Ruth Mary.

I wondered, "Didn't this ever happen to people one hundred years ago?"

Bruce thought this was a very silly question because there was no electricity one hundred years ago. He was a trifle disconcerted when I asked why there was no electricity then. There just was not any was the only reason he could give. Then he decided that electricity had not been invented one hundred years ago.

Dick had a better reason. "There was electricity at that time but it hadn't been discovered as yet."

On being asked who discovered electricity and where it was discovered, he did not make such a definite reply.

"Wasn't it Benjamin Franklin? I read something about it in a book. He was out in a thunderstorm flying a kite and got electricity out of the sky. I saw a picture of it."

"Do you mean a picture showing the electricity?"

"Oh, no. The picture showed him using the kite to draw the electricity out of a cloud, but you couldn't see
the electricity. It's invisible."

Jackie was quite disturbed by this explanation. "Why I always thought electricity was a crooked white streak," he said, "I saw that same picture and the electricity is coming out of the key in his hand."

"That was a picture of the lightning," said Marie.

"What is lightning?"

When Ruth Mary said that lightning is electricity jumping between the clouds, Mason wanted to know what makes it jump. Junior wondered how it gets in the clouds in the first place, and Jackie was curious as to why it makes a crackling sound. Billy said that he had always wondered why someone had not tried to invent a way to use lightning.

When I suggested that we try to find out why lightning does the things they had mentioned, several of the class eagerly volunteered to look for the information. The "Book of Knowledge" and various other references and science books in the library were suggested as sources of material.

"Would you say that damage to electric lines is the worst thing that storms do?" I asked in an attempt to return to the original question.

A number of people disagreed with this statement. They thought that there were many worse things that happen during bad storms. However, they were willing to admit that doing without electricity is quite an inconvenience today.
"Has electricity been in use very long?" I asked.

"I don't know how long," said Howard, "But it hasn't been very long. It's been used probably about twenty-five years."

Several thought that it had been used much longer than twenty-five years. James estimated that twenty-five years ago would be 1915. He was certain that electric lights had been used before then. As no one seemed to have any definite information concerning this date, we again decided that additional research was necessary to answer our question.

"Suppose that we were suddenly told that we would have no more electricity. Would the lack of electricity make any difference to our way of living?"

In reply to this question, a number of devices that would be unusable without electricity were mentioned. In some homes no cooking could be done because the stoves are run by electricity. Another realization was that picture shows would have to close. There would be no street lights. Radios would not work. Refrigerators, irons, washing machines, machinery in mills and factories all run by electricity. They were all conscious of the difference electricity makes in our way of living.

"How can you tell whether there is any electricity? Can you see it, or was Dick right in saying that electricity
Jack said that in a light electricity looks white. Corel disagreed. "You don't see the electricity. You just see what it does."

"But the light's the electricity," argued Jack.

Charles said, "You have to turn on the electricity before you can have light."

The class did not think so. What was seen was not the electricity itself, but just what it did. Just like gravity and magnets, was another suggestion. The way to tell if the electricity is off is to see whether it does any work.

Charles had another idea. "You can feel electricity. Sometimes it gives you a shock."

As this was the end of the period, I reminded the class of the extra reading and suggested that they try to find how electricity was first discovered.

Analysis

Before starting this unit the class had asked me what we were going to study next. When electricity was mentioned, most of the group were quite interested. A few of the girls wanted to study about "Stars," one of the fifth grade units. Several objected because they were afraid of electricity. In spite of these objections, the majority of the class were eager to begin. Can we make an electric map?
Can I bring my telegraph set? Why not make a telegraph set and send messages to other rooms? These questions showed that the class was interested, but their main desire was to do something with electricity rather than find out why it did these things.

In an attempt to "unsettle" the subject, questions were asked which would bring out contrasts and raise problems which the class would enjoy trying to solve. It was rather difficult to guide this class to reach adequate conclusions. Some were not willing to try to think through to a solution of their problem but wanted to jump to a conclusion and just stay there. Instability of attention was another difficulty. We could have spent every period flitting delightfully from one subject to another as far as some of the group were concerned.

In order to approach the problem of how electricity is used, a question concerning a recent storm was asked. This gave the class a picture of what happens when a city is without electric power. The picture of damage done by a storm today is compared and contrasted with their idea of what storms did years ago. With this as a starting point many problems arise. The subject of electricity, which had

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been so "settled" that no one was curious as to why it made things "work," became vitally interesting when it was un­settled; and the group began to realize how little they knew about it.

Just what is electricity? Was it discovered or did someone invent it? What relation is there between lightning and the electricity we use? Why is no use made of lightning? What things would we have to do without if we could not use electricity? These questions indicate that inadequacies in knowledge are being sensed. The children began to doubt some of the things they had always before taken for granted.

The unit How Do We Use Electricity in "Discovering Our World, Book III" gives a factual story of what happens when an electric power line is broken down during a storm. It lists a number of ways in which electricity works for us in order to arouse pupil interest in learning how electricity can do these things. In our unit the children formulated their own ideas of what happens when we do not have electric power and, in recalling ways of using electricity, began to wonder about what it is and how it was discovered. The book makes no reference to the work of Franklin or to lightning.

The lesson, however, does not do exactly what it starts out to do. In a lesson of this type it is easy to get "side-tracked." This almost happened when the discussion
of lightning began. This was an excellent opportunity to raise the question concerning how people found out about electricity and what Franklin was trying to do. Instead of proceeding along this line of thought the question of lightning was developed. The reading assignment was too indefinite. The reading should have been motivated by a desire to find what different people thought about electricity, what Franklin thought, and what the facts now seem to tell us. Static electricity could have been introduced by some simple experiments such as producing sparks or causing a balloon to stick to the wall.

Lesson 2.

During this period reports about lightning and early experiments with electricity were presented. The children had read stories about static electricity and were eager to perform some of the suggested experiments.

Marie rubbed a balloon on her skirt and made it stick to the wall. Gerald had a comb that he used to pick up paper. For those who had not read, Howard told how the Greeks observed that a piece of amber rubbed with cloth would attract feathers and pieces of paper.\(^1\) Dick told about Dr. Gilbert's experiments and the origin of the term

\(^1\) Craig and Johnson, "Our Earth and Its Story." Ginn and Co. 1932.
electricity from the Greek word for amber.¹ Most of the class had read about Franklin's experiment. Several knew what Franklin had done but had no idea why he wanted to bring electricity out of the clouds. Mary thought he wanted to find if electricity and lightning are the same thing. This seemed to be a sensible suggestion and was verified by referring to the historical account of the experiments.² The questions which had arisen in the previous lesson were answered satisfactorily.

Billy was not satisfied because he had not been able to find why you could not use lightning. He thought some way could be invested to get it out of the sky. Dick reminded him that Franklin had charged a Leyden jar during a thunderstorm but this was dangerous because electricity might strike and kill a person.

Charles said that the only time this electricity could be used would be during a thunderstorm, and in summer because we do not have lightning in winter. For this reason, he hardly thought it worthwhile to invent a machine to get electricity from the clouds.

Ruth Mary had a better reason, she thought. "The

2. Ibid.
electricity in the clouds isn't the same kind we use."

"Isn't all electricity alike?" I asked in surprise.

"I thought electricity was just electricity," said Jack.

Ruth Mary was ready to defend her statement. "No," she said, "there are two kinds. Static electricity just stays in one place and current electricity moves along a path. Current electricity is the kind we use."

"Which kind is lightning?" Billy Dean wanted to know. Upon being told that lightning is static electricity, he protested that it moves when it jumps between the clouds. Ruth Mary decided that it would be better to say that static electricity either stays in one place or moves by jumping.

"Then you would say that Billy jumping or standing still is a different boy from Billy walking or running?"

The children were quite amused. Billy, especially, was sure he was the same boy. Ruth Mary realized that what she had been talking about was not two kinds of electricity, but simply two things that electricity did.

"Would you think that electricity produced by friction would be very convenient to use?"

Jack agreed that it would not.

This idea was also agreeable to Junior. "If electricity does work for us," he added, "it will have to move; we would not want it to jump or stay in one place."
"If Ruth Mary is right in saying that electricity can do two different things, some of you have observed these things. If you have, which do you think is more practical?"

At this time the class weighed the evidence to decide if electricity can do two things. They decided that Ruth Mary was right. They were not able to think of any place where static electricity can be used. However, they did mention a number of places where moving electricity could be used. According to this, current electricity seemed to be more usable.

One of the devices that was suggested as needing a current of electricity to make it work was the electric map in the classroom. I asked where the map gets this current of electricity. The answer was it comes from a dry cell.

When a question was asked regarding how the electricity gets into a dry cell, no one had any theory about it; but they did suggest that we tear up an old cell and see if we could "find the electricity." I agreed to the suggestion, although I did not know just what they expected to find. The zinc cup, black mixture, and carbon rod were taken out. Dick noticed that there were some holes in the zinc cup. The black mixture seemed rather damp.

"What do you think happened in this cell?" I asked. "It's dead," Victor observed. "All the electricity is used up," said Alex.
Jackie was quite impatient. "Well, where was the electricity?"

"The cell made it," Junior told him.

"If the cell made the electricity, why did it stop making it?" I asked.

Dick was not quite certain about this. He was sure he could find out by reading our science book.¹ The class read the selection in their books and in a few minutes they were eager to explain just what makes a dry cell work.²

Dirk had a scientific answer. "The black substance is a mixture of chemicals like I have in my chemistry set. It reacts with the zinc and eats holes in the zinc cup. This starts the electricity moving. When all of the chemical change has taken place, the black mixture dries up and we say the cell is dead because it doesn't make electricity any more."

The class was quite impressed by Dirk's knowledge. They did not understand just what a chemical change is, but they did have the impression that it is something that happens within the cell to start the electric current flowing.

"Do we use dry cells very much?" I asked.

Flash lights, battery radios, some toys, our map, and

bells were mentioned.

"Don't they run such things as lights or an electric iron?" I asked.

"No," said Marie, "they wear out too quickly. We have to get new batteries for our flash light all the time."

"Aren't they cheap to buy?"

"Yes," said Charles, "but they aren't powerful enough to run things. They won't even make our telegraph set buzz. We have to use a transformer."

As these seemed to be very good reasons for not using dry cells more widely, I asked if anyone knew of any other kinds of cells. No one seemed to know what I was talking about.

Then I asked, "Where does a car get the electricity that runs its lights?"

"It has a battery," Donald told me.

"What is a battery?" I asked.

"It's what makes the electricity."

"How is this done?" I asked.

Howard had an excellent suggestion. "It's a thing that has three little cups in it. You put water in the cups."

"Do you know of any name for these cups?"

"They're called cells," Dirk volunteered. "They have sulphuric acid in them."

"If a liquid is used in these cells, what would be a
good name for them?" I asked.

"Wet cells?"

"Of course. Is there any other way in which a wet cell is different from a dry cell?"

As this question brought only a few superficial answers, I asked what could be done with a dry cell when it went "dead."

"Nothing. Just throw it away and get a new one."

Here Jackie got the idea. "You don't throw a wet-cell battery away when it goes dead. It can be recharged. (The teacher later learned that all wet-cells cannot be recharged.)"

"How is this done?"

"Oh, some electricity is run into it."

Bruce added that it is attached to a generator that puts electricity into it.

"Did you ever hear any other name for this kind of a battery?"

With a few references to recalling what the battery does with the electricity until it is needed by the car, and how the car itself can charge the battery, the term storage battery was developed.

"I wonder why we talk about a dry cell, a wet cell, and a battery. It seems to me that all of them do the same thing. Is there any difference between a cell and a battery?"
Corel thought there is, because their car has three cells in the battery. Anita said that her flash light has two cells in the battery. From these observations we concluded that when more than one cell is used a group of cells is called a battery. Howard thought that the amount of work a battery can do depends upon how many cells are in it. The more cells it has, the more electricity it can make. This explanation seemed quite reasonable.

Jackie was afraid we would leave out something and asked if there was not another way of making electricity. When asked why he thought so, he said he knew our lights were not run by batteries; so he thought there must be another way of making electricity.

Here the idea of a generator, or a machine to make electricity, was brought out. We discussed what a generator is like and how it makes a current of electricity start flowing. A number of sources of power were mentioned. Some of these were steam, water, wind chargers, and gasoline motors. After discussing the relative merits of these ways of making electricity, we decided that a generator is the most practical method of making a strong current of electricity.

At the close of the period, the class was asked to think about what they would do if they wanted to put electricity in their homes. Another suggestion was that they
examine electrical appliances to see how the electricity is conveyed to them. Carol volunteered to bring an old electric toaster to school, and Marie said she could bring an old iron.

**Analysis**

In this lesson the children are led from a discussion of static electricity and lightning to raising questions about how the electricity we use is made. A comparison is also made of the different ways of producing electricity in order to find where each method is used.

There are several places in this lesson where we see good examples of reflective thinking taking place. When Billy wanted to find out why lightning was not put to some practical use, three suggestions were made. All of these were reasonable suggestions, and the one which seemed to be most applicable was chosen. The same thing happened when the suitability of using dry cells in places where a continuous flow of electricity is desired is questioned. Here again the most practical suggestion is chosen by the children. They see the answer that is most correct in relation to the other facts pertaining to the situation. In using this procedure rather than just the "right-answer" technique, the class learns to consider evidence before making a
Instead of having the group read about a dry cell before examining it, we found the different parts and then read to see just how they worked together to make electricity. In this way their reading was to find a solution to the problem of how a dry cell works.

The lesson errs in attempting to cover too much material. The reports given at the beginning of the period could have been used more profitably as material for a reflective study rather than merely restating facts read. If the lesson had been started with a few magic tricks using static electricity, interest would have been aroused as the class attempted to explain these phenomena. The following discussion of static electricity and early electrical experimentation would have involved reflection-level thinking as well as recollection of facts. There was enough material in the first part of the lesson to cover an entire period.

The difficulty with the type of reports that were given is that they are of little value to anyone but the person reporting. If the same material is brought out in order to solve a problem, to complete understanding of a concept, or to clarify a disputed point, it has much more significance.

The material in the text is introduced with the problems: "How can you make an electromagnet?" and "Where does electricity come from?" These questions are answered in the discussion which brings out the idea that electricity is a force. The answers to the questions are ready-made and the pupils using the text have no need to think for themselves.

Lesson 3.

"Yesterday we talked about ways of making electricity. Suppose you lived in a town where there was no electricity and you were given the job of figuring out a way of making electricity so the people could use it in their homes. What would you do?"

Bruce said that you would put wires in their houses. There were several objections to this answer. Corel told him that the wires will do no good unless there is a power plant in the town. When asked what a power plant is, she said it is a place where electricity is made. Dick added that it is where the generators, that we discussed the day before, are kept and that all the electricity we use comes from the power plant.

"What would you do for electricity if you lived in a

place where there was no power plant?"

Several of the girls thought that you would have to get along without electricity as their grandmothers did on the farm. Junior said that farmers could buy machines that make electricity. When asked what makes the machine run, he thought they ran with a motor. Howard added that a Delco plant is run by a gasoline motor. Bruce thought that wind power could be used. He told about the wind charger that makes electricity run farm radios.

The class tried to decide which way of furnishing electricity would be best in a town. We decided that a generator run by moving water or by steam would furnish the most electricity in the least expensive way. If a person lived close enough to some large source of power such as Niagara Falls or Boulder Dam, electric power could be brought in by wires.

"Is this all that is necessary in order to have electricity in your home?"

Leiland said that you would have to have some wires and fixtures in the house. Even in Lawrence, not all the houses have electricity in them. Any house can have electricity if the owner wanted to go to the expense of having it put in.

"Is it necessary to have wires or can we use some other material?" I asked.
The class was sure wire is necessary, but they did not know just why. Electricity travels along wire was one of the answers. We decided that we had better read to find out just why wire is used. The story in one of the science books gives a simple explanation of conduction. It explains that everything is made of atoms which carry charges of electricity. In some materials these electrons are easily detached from their atoms and travel through the material. These materials are called good conductors. Other materials do not let the electrons flow so easily; these materials are called poor conductors or insulators. If these charges are started moving, each atom passes its charge to the next one. The best conductor is copper wire because it lets the current flow along easily.

We played the game, suggested by the story in the book, in which the members of the class represented atoms and each held a book which represented an electron. When an extra person stepped into the circle, the "atom" next to him passed him his "electron" and the charges of electricity started flowing.

"How would you connect these wires to a light bulb to make it light?" I asked.
Paul was eager to show how this is done. I asked him what materials he needed and he mentioned wire and the light bulb.

"Are you sure you can make the bulb light with just those things?"

He thought so but Leiland told him he would need some electricity. We decided that the best way to get a small amount of electricity is to use a dry cell. Paul took the piece of copper wire (he was given only one piece) and wrapped it around one of the binding posts. He could not find any place to attach the wire to the light bulb and realized that he needed a socket. We found one and screwed the bulb into it. Paul connected it to the other end of the wire. Everyone could see that the bulb did not light. Several of the group said that Paul should have used two wires.

"Aren't the dry cell and the bulb connected?" I asked. "The dry cell makes electricity which travels on wires to where it is needed. Could something be wrong with the cell?"

Someone suggested that the bulb might be burnt out. I tried to agree but Dirk was still protesting that we had not connected the cell and the bulb correctly. Paul wanted to use two wires. He was certain that this would cause the light to burn. Before consenting to this, I wanted to know why Paul thought we needed two wires. You just have to have them to make the light work was the best answer the class
could give until Carol said that a complete circuit is necessary.

"What is a complete circuit?" I wanted to know. By this time most of the class were convinced that I knew very little about electricity.

"It's the path electricity follows," Carol said.

"Why must it follow a path?" I asked.

"Because it travels in a circle," answered Donald.

"Why?"

At this Billy commented that we were just going around in circles. Dirk said we were just like the electricity. I decided that we had better finish connecting the bulb and Paul connected the other two binding posts of the bulb socket and the dry cell. Immediately the bulb lighted. Then we traced the electricity from the dry cell to the light bulb and saw that the other wire carried electricity back to the cell.

"What is a complete circuit?" I asked again.

Ruth Mary said that it is the path electricity follows in order to get back to the place where it starts.

"What happens when I disconnect one of these wires?" I asked.

"I think the light will go out," was Anita's answer.

We disconnected the wire and saw that the light did go out. This was explained as a break in the circuit. If
any part of a circuit is missing, the electricity will not start on its journey. Electricity always has to be sure of a way to come home before it will start on its path.

What happens when a light is turned on? We pressed the switch and the light went on. Blossom explained that this completes the circuit just like attaching the wire to the dry cell. The electricity could go through the light bulb and back.

"Where is back?"

Victor said it is the place where the electricity is made. This is the power plant.

Billy explained what happens when the light is turned off.

We examined the electric questioner to see how a complete circuit is made in it.

The class asked to examine the electric toaster to see how it gets electricity.

Lesson 3. (Continued)

The next day the first part of the period was used to give reports on how different appliances get a complete circuit of electricity. Several people were confused by the cord. They thought that it was only one wire until we examined it and saw the two wires twisted together.

"Could you make a plug with just one prong?"
Marian thought you could. When she was asked if any were ever made like that she could not remember ever seeing one. Paul thought that two prongs made it stick in the socket better. Dick thought that the prongs were connected to the two wires. This seemed like a logical explanation and an examination of the plug showed that it is the correct one.

"How does the electricity get into the house?" asked Ramona.

The first explanation was that a wire brings it into the house. I agreed with this but I was immediately contradicted. Howard said that two wires are needed. When asked why, he said that there always are two wires running into the house. Dick agreed that there are two wires but one carries the electricity away from the house. This is the complete circuit that electricity must always have.

"Can you suggest any easier way of turning the light on and off in this circuit?" I asked, showing them the circuit we had made with the dry cell and the light bulb. In order to turn the light off and on we had been connecting and disconnecting the wire that was attached to one of the binding posts.

Mary thought that we might use a switch but she did not know why. Marie said that a switch makes the connection so the circuit is completed. When it turns off the light it breaks the circuit.
"What could we use for the switch in our circuit?"

Jackie suggested that we use a push button. He had seen a picture of one in a book on electricity. The push button pressed down on a spring which connects the two binding posts and completes the circuit. Releasing the spring makes a gap so the electricity cannot flow.

"Is there any other way of controlling electricity besides turning it on and off?" I asked.

No one seemed to have any ideas about this. I then asked if a switch to turn the electricity on and off and wires to convey it are the only things ever found in a circuit. Dick and several others objected. Charles said that electric trains use a transformer.

"Why isn't the electric train connected with the regular circuit?"

"The current is so strong that the train would go too fast and it might blow up," he answered.

"What does the transformer do then?"

The fact that it makes the current weaker was brought out.

"Can a current be made stronger?" I asked.

There was a difference of opinion here until someone remembered that the buzzer on the electric questioner is 1. Keeler, Katherine, "Working with Electricity." Macmillan. 1936.
louder when it is connected to all of the dry cells. We learned that this is called "stepping up" a current. A transformer may either "step up" or "step down" a current.¹

Corel wanted to know why the end of a wire had to be scraped before it is fastened to the dry cell. Leiland said that he had always been curious as to how an electric chair works. How can electricity kill a person was another question. I asked the class to see if they could find out why electricity is sometimes dangerous.

Analysis

The class was confronted with a practical problem: how to go about putting electricity in a home. Solving this problem required much information about electricity and an understanding of how electricity travels. Two class periods were necessary in order to develop the concept. In discussing ways of making electricity the children saw how people who live on farms can furnish their own electricity.

In developing this lesson an attempt was made to keep "unsettling" questions so that the class would feel that they were accomplishing something and not just "going around in circles." Instead of giving Paul all the materials he needed to make a complete circuit, some were purposely

omitted so that he would sense that something was lacking. The class had to help him see what was needed. The right way of wiring a circuit can be learned by first wiring it wrong. Another thing that kept the class interested was that they were led to think that the instructor did not know what they were talking about. This led them to give reasons for their suggestions.

The previous year, as a part of a similar unit on electricity, the sixth grade had made an electric questioner to show how a complete circuit works. They made a wooden frame, drew and painted a large map of the United States, wrote a hundred questions that were answered by places on the map, put screws in these places and connected them with the questions. When the right answer was found, a complete circuit would be made and a buzzer would ring. This project took several weeks to be completed. At its close the class had no better conception of an electric circuit than this year's class had after two periods of reflective study and discussion.

After finding out how electricity is brought to their homes, the children began to wonder how it can be turned on and off. From the simple demonstration with the push button in the light circuit it was easy for them to see how a switch opens and closes a circuit. These children had been turning electricity on and off all their lives, but never before had
they wondered what really happens when the switch is pressed. Most of them had noticed the two wires carrying electricity into their homes without ever wondering why it was necessary to have two wires.

The question as to whether a plug has one or two prongs and whether a plug with one prong would "work" began a discussion of how a connection is made. After examining a plug many of the group learned how to repair one.

The close of the second period left the class having answered a number of questions that had arisen in connection with the original problem of installing electricity in a home and with additional problems to be solved. A number of the class were doing independent reading in their library period and were asking where they could find other books about electricity.

As a whole, the two periods were quite successful. Both attention and interest were excellent. The problem that we were attempting to solve was challenging and the response to it was satisfactory. A number of different ideas were brought together and clarified while the original problem was being solved. The children were widening their knowledge of the world about them and at the same time were thinking for themselves.
Lesson 4.

"What causes a car horn to keep honking sometimes?"
I asked at the beginning of this period. The day before we had talked about controlling a current of electricity. The question had been asked as to why electricity is dangerous.

"It does that when there is a short in the horn," Charles said.

"What is a 'short'?" I asked.

He was rather uncertain but he thought it has something to do with the wiring. Sometimes when there is a short the horn will not honk at all.

"Do you know what causes a 'short'?"

Paul thought they occurred when the wires get old. Dick said that the insulation wears off the wires. When asked what insulation is, he explained that it is the covering on the wires.

"Why is covering needed? Won't bare wire carry electricity?"

Bare wires would carry electricity but are dangerous. We decided to connect our light bulb to the dry cell with bare wire. The bulb lighted and the children were quite satisfied that it is all right to use bare wire. It is covered so it will cost more was one explanation. Junior still thought that bare wires give electric shocks.

I brought the wires together trying not to let the
the class see what I was doing. The light went out. They could see that the wires were still connected to the dry cell and the socket; they could not explain what had happened. Marie suggested that the light had "burnt out" but changed her mind when she saw it light again. Charles decided that I must have "shorted" the wire. "Show us what you did," they clamored.

When I showed them that all I had done was to touch the two wires together, several immediately got the idea. Dick said that when the wires touched that made a complete circuit without going through the light bulb. We touched the wires and found that they were hot up to the place where they crossed.

"Would you say that this a complete circuit?" I asked.

Some of them thought so but we finally decided that the circuit is not complete unless it does its work. I explained that electricity is lazy and will always take the short path home if it can. This was a complete circuit but it was a shorter one.

"Would electricity be very useful if it could go home any time it wanted to?"

The class could see that there should be some way of making electricity go where it is to be used. They decided that this must be the reason why wires are covered. When asked what materials could be used to cover the wires, several
of the class thought the material should be one that would not burn as the wires would make it hot.

"Should it be a material that will let electricity flow through it?"

Mary thought that it should not carry electricity. As an experiment to decide what materials will not carry electricity, we connected the dry cell and the light with string, rubber bands, thread, and iron wire. None of them made the bulb light but the iron wire became a little warmer we thought. We found that enamel, glass, and porcelain are also used as insulators. Jackie remembered that he had wondered why the electric-light poles had glass rods on them.

When I asked whether the reason a short circuit is dangerous is because it does not do its work properly, several people agreed. They mentioned that a short circuit may cause the car lights to go out, which is dangerous. It may keep the motor from running. Jacqueline said that the worst thing about a short circuit is that it may cause a fire. A number of incidents telling of fires caused by short circuits were related at this point.

"Why do short circuits cause fires?" I asked.

Dirk said that the wires got so hot when they touch that they set things on fire. Billy wanted to know if every time there was a short circuit there was also a fire. James said that the wires had to get extremely hot before they
caused a fire.

"Does anything else ever happen when electricity makes a short circuit?"

After a few minutes, Dirk had an idea—a fuse burns out. With this lead the class discussed how a fuse works. They wanted to know why it blows out; what happens when it does; and why a blown-out fuse cannot be fixed.

"The lights go off when a fuse blows out," said Mary.
"Even when the short circuit is in the iron cord?" I asked.

She was not very sure about this but she thought so. When I asked where you would look for the fuse, Victor said it was where the electric wires come into the house. Charles added that both wires that carry the current lead into the fuse so all the current passes through the fuse before it comes into the house.

Since the children were uncertain about what happens when a fuse blows, we examined one. In the fuse we saw the thin strip of metal. To show what happens to the fuse, I connected two pieces of wire to the dry cell and made a connection between them with a piece of tinfoil. As the tinfoil became hot, we saw that it melted and fell apart.

"Why does the tinfoil melt?" I asked. "Does it get hotter than the copper wire?"

"It has a lower melting temperature," answered Dirk.
He explained that tinfoil does not require as much heat to melt as copper wire does.

"Why do the lights go out when there is a short circuit in the iron cord?" I asked.

Howard explained that when the wires get hot during a short circuit the little strip of metal in the fuse melts and breaks. This breaks the circuit and no more electricity can come in until the fuse is replaced.

Bruce Dean asked, "Why can't you fix a fuse with a penny?"

Leiland knew that a penny would make a fuse "work." Dick thought it would be dangerous. Bruce wanted to know why fixing the fuse would be dangerous.

"What is it that you want the metal in the fuse to do?"

"Melt when it gets hot and turn off the electricity," was the answer.

"What about a penny? Will it melt when it gets hot?" I asked Bruce Dean.

Bruce Dean knew that a penny is made of copper, a good conductor of electricity. He guessed that it would not melt soon enough to turn off the electricity before a fire started.

"What is the first thing that should be done when a fuse blows out?"

"Put in a new fuse," was Jackie's suggestion.
Several children objected because they thought the fuse would just blow out again. After discussing various things to do, we decided that first the short circuit should be located: then the appliance in which it occurred should be disconnected or the circuit repaired by putting in new wires. After this is done, a new fuse can be put in.

"Can just any kind of fuse be used?" I asked.

The question arose as to whether all fuses are alike. A committee was appointed to investigate fuses and report what they found about them. A suggestion was made that each person "survey" his home to see where the electricity enters the house and where the fuses are. Another suggestion was to find out how many things in their homes are run by electricity.

Analysis

In this lesson it was intended that a contrast between the use of electricity, if properly controlled, and its potentiality of being harmful be brought out. Although the class enjoyed the lesson, the procedure did not bring out this contrast as clearly as a different method might have done.

The difficulty was that the initial question about the automobile horn was too narrow in its scope. Opening the discussion with a question about the different causes of fire probably would have presented more possibilities. From
this leading question, a discussion of the danger of bare wires, the use of insulation, and the materials suitable for insulation purposes, could have been developed.

The question of why a short circuit may either make a horn honk continuously or not at all was suggested but was not developed. Of course, several members of the group may have wondered why a short circuit may do either of two things and may have tried to find out for themselves. Sometimes dropping a subject before it is completed stimulates independent research and thought. As far as the understanding of the class as a whole was concerned, it would have been more worthwhile to complete the discussion.

Asking the children to explain why the light went out, without letting them see that the wires were crossed, was used as a device to start reflective thinking. Children like mysteries. There were several reasons why the light might have gone out. When the children finally saw what had caused it to go out, they understood what makes a short circuit.

Reflective thinking also took place in developing the idea of a fuse. The number of children who, although familiar with the expression "a fuse blew out," did not know what a fuse looks like or why it is used was rather surprising.

The experiment with the tinfoil should have been done before the fuse was examined. If the circuit had had a light in it, the fact that the melting of the tinfoil breaks a
connection would have been very evident. After this, the fuse could have been compared with the tinfoil. Comparing a burnt-out fuse with a good one also would have helped to develop the idea of what happens to a fuse when it "blows out."

Bruce Dean's question about fixing a fuse with a penny could have been answered by telling the reason why this is not safe. Letting him formulate the reason by seeing the relation between the melting point of copper and the function of a fuse gave him, as well as the rest of the class, not only the answer but the way of arriving at the answer.

In answering the question of what to do when a fuse blows out, the children arrived at the correct solution by a democratic method. The first suggestion, "Put in a new fuse," was only partially correct. The other suggestions rounded out this idea by telling what must be done before the fuse can be put in and why just putting in a new fuse may not work.

Lesson 5.

At the beginning of the period, the committee on "fuses" reported what they had found out. Several safety rules were formulated concerning fuses. One rule was that a "blow-out" fuse should be replaced instead of being repaired.
Another was that different currents need different fuses. The fuse that is put back must always carry the same electric current as the one it replaces.

In the various homes a number of electrical appliances had been found. The list included electric toasters, waffle irons, stove, clocks, heating pads, irons, vacuum cleaners, fans, dish-washer, lights, refrigerators, sewing machines, percolators, and radios.

The question "How are all these appliances alike?" was raised. Everyone thought this was quite simple. They all "run" by electricity. When asked what was meant by "run," one girl thought that it meant move. She was rather disconcerted when asked if the electric light moves. Another suggestion was that electricity made all of these things work. How? Do they all work in the same way? These questions were baffling until group was asked why we use a toaster. A toaster toasts bread. How? The wires get hot and that does the work.

"Can we say that electricity works for us by making all things hot?"

No, because a fan and a clock do not get hot. Obviously, electricity makes things work in different ways. Some devices move and others get hot.

"Suppose that you wanted to make a toaster. What would you do?"
Looking at a toaster, we saw that it is made of fine wires. When connected to the electric current, the wires in the toaster become red-hot.

"Do all wires get hot when electricity passes through?"

Apparently not, because copper wires are used to carry electricity and would be quite a nuisance if they became red-hot every time the current was turned on. To see if we could find which wires got the hottest, we passed a current of electricity through fine copper wire, heavy copper wire, fine iron wire, and heavy iron wire by connecting them to the binding posts of a dry cell. The fine iron wire became the hottest and the heavy copper wire stayed the coolest. This was explained by saying that in fine wire and in poor conductors of electricity the current cannot flow along easily but has to push hard and so heats the wire. The wire used in the toaster is a poor conductor.

"Why does an iron get hot?"

Evidently, an iron must also have some of these fine wires. Tearing an old iron apart proved this to be a correct assumption. Jackie found the thin sheet of mica around which the wires were wrapped and wanted to know why it was in the iron. The toaster also had a sheet of mica in it. Does mica conduct electricity? We tried mica in our dry cell circuit and found that it is not a conductor of electricity.
From this discussion, the class decided that, if electricity is to be used to make heat, wires must be used that are poor conductors of electricity so they will become hot when the electricity pushes hard in order to go through them. Appliances using electricity to make heat were renamed. All of these work on the same principle.

"How do the rest of these appliances work?" I asked with reference to the list of electrical devices we had made.

Howard said that electricity made them move, but Dick said that a light does not move.

"What does electricity do to make a light?"

Again the question of the identity of the light and electricity was raised. Ruth Mary clarified this point by saying that the light was the result of electricity passing through the wires. When the wires got very hot they glow and give off light.

"Is this any different from the earlier ways of making light?"

Several of the group thought it is because it makes a brighter light and lights instantly. Torches, candles, kerosene lights, and gas lights were mentioned as some earlier types of lights. All of these lights had to be ignited before they would burn. The disadvantage of the earlier lights was that the material which gave the light
was consumed by burning.

"What is the advantage of the electric light?"

This advantage was seen to be that the wire gives off light when it gets hot but it does not burn and can be used for a long time.

"Do you think it was easy to find such a material?"

Opinions about this were quite divided. Most of the children who argued that it was easy were so accustomed to accepting the things that we enjoy today that they did not realize the difficulty of making them. Some one suggested that we read about some of the first lights and about the invention of the electric light. The class period ended with this suggestion as the assignment for the next lesson.

Analysis

The discussion in this lesson was started by raising the question, "How are all electrical appliances alike?" In answering the question, many other problems arose. Do all electrical devices "work" in the same way? If not, what is the difference? How is a toaster made? In what way is a toaster like an iron? Why does the iron get hot? Why do not all wires that have electricity passing through them get hot? Does mica conduct electricity? What relation is there between making heat by electricity and making light? These questions involved reflective thinking that helped to
develop an understanding of how electricity does work for us. As a part of the problem, the fact is brought out that electricity works for us in more ways than one.

This should have been one of the most interesting lessons in the unit because "How does it work?" is a matter about which children are eager to know. Although the questions raised were significant to the conception that was being developed, they were teacher-questions rather than pupil-questions. They were questions that should have risen spontaneously in an active learning situation. Instead, they were asked in a routine fashion and answered by pupils who were anxious to please the teacher.¹

Part of this difficulty was due to anticipation of an assembly program which was to follow the science period. The pupils were thinking about the assembly program and the teacher was trying to cover the material planned for this lesson. With this teacher-pupil attitude it was difficult to hold the interest of the class. This was a time when intriguing questions should have been raised. Making a false statement or agreeing with an absurdity just to raise an issue might have helped the situation.² The teacher should

have been more concerned with diverting the attention of the class from the assembly program than with covering the material.

The latter part of the lesson was more interesting because the discussion about the electric light raised conflicts. How are electric lights different from other lights brings out a contrast that shows clearly the advantage of the electric light. The question of whether the incandescent light was easy to invent stimulated interest in reading about its history.

Lesson 6.

The first part of this period was used to read about electric lights. The stories in our books told about the arc light and the work of Edison in inventing the incandescent lamp. I asked if it is correct to say "an electric light burns." Several children were quite positive that it is because "we always say that." I said that we would talk about it after the reading period.

Before asking for the reading reports. I asked if anything in the reading had seemed puzzling. Marie said she wondered why it had taken so long to make an electric light after people found out that very hot wires will give off light.

"Perhaps the need for such a light was not felt," I
suggested. I remarked that people were used to going to bed early. Marie was quite serious because she thought that people had always wanted good lights. The stories about the danger of going into the streets of poorly lighted cities had impressed her as evidence of the need for lights.

Dick asked, "What were the first electric light like?"

Junior was pretty certain that they were not like the ones we have today. Jackie thought they were more like a gas light. When I asked if anyone had read about Sir Humphrey Davy, Corel remembered that he had made an arc light. I showed the class the picture in the "World Book" of an arc light and gave a simple explanation of how it works.

"Do you know of any place where such a light is still used?"

No one could answer this question so I asked if they had ever seen a searchlight. Of course they had. How is it different from other lights? It is brighter. In what places are such lights needed. In thinking of places that need bright lights, the class decided that lighthouses would need lights like this. Moving picture machines were also mentioned.

"Why weren't arc lights used in lighting homes?" I asked.

James thought that they might have been dangerous. Dick, who had read more of the story, said that they were too
expensive, especially when two thousand cells had to be used to furnish the current. Ruth Marry thought that they were too bright to use in a small room. All of these reasons indicated that it would have been impractical to use arc lights. I told them that after the dynamo was invented that arc lights were used to light city streets.

Our question of why it had taken so long to develop an incandescent lamp had not as yet been answered satisfactorily. Evidently it had not been easy to make such a light. Why had the task been so difficult? Billy said that the inventors had to find just exactly the right material. Why? So the light would work.

"What kind of material was necessary?"

"Well, one that would get hot enough to give a light," he thought.

"It has to get hot without melting," Dick added.

"What will make it get hot?" I asked.

The electricity, of course. A few more questions brought out the idea that the wire should be a poor conductor of electricity. This was an explanation of the difficulty of making an electric light. In fact, until just about sixty years ago, the task had seemed impossible. In 1878, a group of scientists had decided that this was an unsolvable problem.

"But Edison made a light," argued Howard, "Why could
he make one when these other scientists couldn't?"

What had Edison done that the other scientists did not do? What was necessary in order to make a light that would work? In answering these questions, the class began to appreciate the ingenuity and perseverance of Edison. They named the different materials that he had tried and criticized them as to whether or not they would work. The discussion of his experiments with platinum wire brought out the reason for the invention of the glass bulb.  

We had finished talking about the carbon filament "burning" for forty-five hours before it broke when Mason had an idea.

"Didn't you say that an electric light doesn't burn?"

"I asked if it is correct to say that an electric light burns," I answered. "Do you think it is?"

Ruth Mary said that the filament did not really burn because if it did it could not be used again. When Howard wanted to know why everybody says that a light burns, I asked if he believed that the sun "comes up" in the morning and "goes down" at night. Of course not! He knew that it is the earth that moves, not the sun. When I said that "everybody says that," he began to understand.

Jackie was puzzled about something. "Do the lights

we use now have carbon threads in them? I thought they had wires in them."

We examined an electric light bulb and compared it with the picture of Edison's incandescent lamp. Why did our bulb have a coiled wire in it? We finally decided that a long wire would give more light than a short one and by coiling a long wire it would fit into a smaller space. Why did one lamp have a short filament and the other a long one? Were the filaments made of the same material? Dick said that our light bulb had tungsten wire in it. I asked why copper wire is not used. It conducts electricity too well and does not get hot. Is tungsten a good conductor? Evidently not, they reasoned, or it would not be used in light bulbs where a poor conductor that will get very hot is needed. Since tungsten is a better conductor than carbon, a long wire of it is needed to offer the same resistance as a short carbon thread.

The advantages of the tungsten light are that it burns a long time, gives a bright light, and does not use as much electricity as a carbon-filament lamp.

"Why does an electric light sometimes fail to light when the circuit is closed?"

The wire might be broken was the first answer. When asked what he meant by this, Gerald replied that the electricity could not get to the light. The light is "burnt out"
was another suggestion. Asked if these were the only reasons, the class began to realize that there might be more than one reason. The bulb might need to be screwed farther into the socket. Maybe the power is off. Perhaps there has been a short circuit and a fuse has "blown-out."

At this point, Junior brought up the question as to why none of the bulbs on a string of Christmas tree lights will light if one burns out. I explained that these lights are connected in series and drew a simple diagram on the board. By erasing one of the lights we saw that the circuit breaks when one of the lights goes out. I asked if this is the way the lights in our homes are wired. Marie thought that it would be inconvenient if they are wired in this way. James was sure that they are not because "you don't have to test all of them when one burns out." I explained that the lights are connected by parallel wiring so when one burns out it does not break the circuit.

Charles said that some lights do not have wires in them. The colored lights on the big signs do not. Anyway he had never seen any wires in the tubes. He did not know that these are called neon lights.

"Is there anything in the light tube?" I asked.

"Jackie thought there was nothing in the tube--at least nothing that could be seen. Of course air could not be seen; it might have air in it. Junior said that the
tubes contain a gas called neon. What does this gas do? No one seemed to have any ideas. What happens when a neon light is turned on? It gives off a red light. If there are no wires in the tube to conduct the electricity, what conducts it across the tube? Ruth Mary read that the the electricity jumps from one end of the tube to the other. Our reference book said that the current passes through the gas, causing the tube to glow with a red light. Here the question arose as to why these conflicting reasons were given. Jackie thought that the book Ruth Mary had read was written when people still believed that the current jumped through the tube.

"Does one of the books have to be wrong?"

Several thought that one of the writers might be wrong. Corel remembered that some of our books talked about the eight planets because they were written before Pluto was discovered. This is the reason why we are always careful to say the nine known planets.

"Could they both be talking about the same thing?"

Of course, this might be possible. I explained that the writers had the same idea in mind but expressed it in different ways. What happens is that a discharge of electricity goes through the tube and causes the gas to glow with I. Parker, Bertha K., "The Book of Electricity." Houghton-Mifflin Co. 1928.
a red light.

"But not all lights are red. Why are some of them other colors?"

We read the explanation given in our reference book which explained this difference in colors.

"What should you do if you find something in a book that does not seem to agree with other facts?" I asked.

Several children thought we should look in as many books as we had to find out if any of the writers agreed. Some books are out-of-date. Marie said that the maps in the geography book would have to be changed after the war is over.

Analysis

Instead of having the class give reports, many of which often are mere repetition of the materials they have read, this material was used to develop a reflective study of how an electric light works.

The initial question as to whether any part of the reading was "puzzling" was a trifle vague, and it was just by chance that it elicited a usable response. In trying to find reasons for the late appearance upon the electrical scene of the incandescent lamp, the story of the arc light is introduced. Here a comparison could have been made between the arc light and the incandescent light to show why the latter is more practical. However, in giving reasons for the limited
use of the arc light, the advantages of the incandescent lamp are merely inferred.

The question of whether an electric light really "burns" raised a conflict of ideas. Do people always mean exactly what they say? Children are apt to interpret such sayings literally. In one class a boy was certain that electric wires must be hollow because people talk about turning on the "juice." This conflict was clarified by a simple question which illustrated the difference.

By contrasting tungsten and carbon-filament lights the desirable features of each were presented and the children decided which one is preferable. Letting the class make this decision for themselves is a more democratic procedure than trying to indoctrinate them by saying that the tungsten lamp is the better and not discussing the other light.

The problem of why a lamp might fail to light involved reflective thinking. Is there more than one reason for this? If so, what are they? How can the real cause be detected? Here is a forked-road situation. This also brought the question of connecting lamps in series in contrast with lamps connected in parallel.

In recalling that some lights do not have wires in them, the question of how electricity can make different colored lights arose. In the fourth grade, one little girl said that she had always thought that electricity was red
because she saw it in these tubes. The sixth grade knew that the red light is not electricity. By comparing the different explanations in the two books the children saw that you sometimes have to pick the "authority" that you can agree with. One book said that the electricity jumps through the tube and the other that the gas conducts the electricity through the tube. Solving this problem involved reflective thinking.

When children begin to question statements, they are beginning to think. When they learn not to believe everything they hear, read, or see, they are not such easy victims of propaganda.

Lesson 7.

At the beginning of this period, I asked the class if they had ever seen an electric crane. There were only a few who had, but several said they had seen pictures of electric cranes and knew what they did. Leiland said they were used in junk yards to pick up pieces of scrap iron. The crane did not hook the pieces of iron. It was a big flat piece of iron hanging on the end of a long arm. It just picked up the iron and then dropped it where it was needed. It "ran" by electricity.

When asked what holds the iron to the crane, Bruce said it is like a magnet. Jacqueline explained that it is
an electromagnet like we made in the fifth grade. When asked to explain what an electromagnet is, she said that it is a piece of iron or steel that becomes a magnet when electricity passes through it.

"How would you make an electromagnet?"

Billy said that one could be made with dry cell, some wire, and a big nail. With the materials on the science table he made an electromagnet with which he picked up paper clips and thumb tacks. He remembered another "trick" and disconnected one of the wires which made the magnet drop its load. What happened? The nail must have lost its magnetism. Why? Because the electricity was no longer flowing through the wire wrapped about it. The advantage of an electromagnet is thus seen to lie in the fact that it can instantly lose its magnetism when the electricity is turned off. Another advantage is that it can be made stronger as we see when two dry cells are used in place of one and when more wire is wound around the nail.

"Can you think of some places where electromagnets are used?"

The first place mentioned was the electric crane. Charles said that his telegraph set has an electromagnet in it. Billy found one in his electric bell. Mason saw one in his electric motor.

"Why do you think these things you have named have
electromagnets in them?" I asked.

In order to answer this question the children had to recall what an electromagnet can do. A magnet attracts articles made of iron and steel. It pulls on these metals and when it is no longer a magnet it drops them. Still they could not see just why the telegraph set, the bell, and the motor have electromagnets in them.

"Why does a bell ring?" I asked.

We decided that we would connect the bell to the dry cell and see if we could find out why it rings. The first thing the children noticed was that the hammer strikes the bell. What makes the hammer move? We looked at it again. Mary noticed that the electromagnet pulled a little piece of iron to which a spring is fastened. The hammer is fastened to this piece of iron so that, when the electromagnet pulls the armature (the name for this little iron piece), the hammer strikes the gong. Why does it move back and forth?

We disconnected the bell and looked at it carefully. Paul found that the little spring touches a place called the contact point. When we press the moving part of the bell or the armature against the electromagnet there is a space between the spring and the contact point. "What does this do?" Gerald thought that this space would break the circuit. The electricity cannot flow over a gap; so it just does not flow at all. Why does the bell keep on ringing if
this happens? Dick decided that something must turn the electricity on again.

Howard asked to examine the bell to see if he could find out what happens. He thought it would be better if we put a push button in the circuit so the bell would just ring when we pushed the button. He did this and then pressed the button. Tracing what happens, he explained that the circuit is completed because the contact point touches the spring and electricity flows through the wires of the electromagnet; the armature is pulled by the magnet, and the hammer strikes the gong. As soon as the armature is pulled away from the contact point, the circuit is broken.

"What happens when you let loose of a spring?"

Several people understood at once. Howard was jubilant. The spring flies back! This was the explanation of how the circuit is again completed. The spring pulls the armature back and touches the contact point again which turns on the electricity. The electromagnet again has force and again the hammer strikes the gong very quickly.

"What does the electromagnet do?"

They see that the electromagnet makes the hammer move. Billy wanted to know if an electromagnet always makes something move. Charles suggested that we try to see what the electromagnets do in his telegraph set. This is the set with which the transformer is used.
"What do you do with a telegraph set?"

You send messages with it. How? It makes a click and, by using a code, a message can be sent. This raised the question of how the "click" is made. Charles wanted to demonstrate his set so he is asked to explain the parts of it and show how it works. We see that it has an electromagnet made by winding insulated wire around a large iron nail driven into a block of wood. Fastened to the wood with a screw is a piece of metal bent until it almost touches the top of the nail. The wire from the electromagnet is attached to two screws in the base of the sounder. One of these wires leads to the transformer and the other to a block of wood having a similar bent metal piece held in place by a screw to which a wire leading to the transformer is attached. Beneath the metal piece is a screw to which the wire from the sounder is attached.

Charles pressed the key and the metal piece on the sounder was pulled down on the electromagnet with a distinct click. When asked what the moving piece is called, an association was made with the moving piece in the bell. The electromagnet pulls the armature and a sound is made.

"How can messages be sent with this instrument?"

All the Boy Scouts knew that messages are sent in code. Junior explained that Samuel F. B. Morse, who made the first telegraph, had worked out a code of dots and dashes.
Junior sent an SOS call on the telegraph set.

"How are the bell and the telegraph set alike?" I asked. They both make sounds was the first answer. Dick said that they both have electromagnet and moving parts which make the sounds.

The other article that had been named as having an electromagnet was Mason's toy motor. What does a motor do? It makes things "run." How? It turns around and around and is fastened by a belt to the thing you want moved. Why does a motor turn? Is there any special part of it that can be moved by electricity? Mason had seen the electromagnet in the motor. If you had not seen it why would you still think that it might have an electromagnet in it? Because the motor has a moving part? Is that any proof? If it is true that the electromagnet always makes devices run by electricity move, the presence of a moving part is proof that the motor contains an electromagnet. The way to prove this would be to see if there are any electrical appliances moved by electricity that do not have electromagnets in them.

The appliances the children were familiar with were run by motors. Fans, washing machines, electric sweepers, and electric mixers all had motors.

"Does a motor work like a bell?"

Remembering that the electromagnet moves the armature of a bell back and forth, the children decided that a motor
is not moved in this way because it turns around. We exam-
ined the motor and found that it has three electromagnets
which whirl around very rapidly when the electricity is
turned on.

Why do the electromagnets whirl around? Why are
several of them needed? As the class was unable to answer
these questions, I suggested that they try to recall the laws
of magnets that they had learned in the fifth grade. How do
magnets act toward each other? Are electromagnets different
from permanent magnets?

These suggestions appeared to apply to our problem:1

(1) Like poles repel each other.
(2) Unlike poles attract each other.
(3) An electromagnet has a north and a south pole.
(4) The poles on an electromagnet can be changed.

These were selected because we were looking for an
explanation of why the magnets moved and how they act toward
each other. With these laws in mind, it was rather simple to
reason that when two electromagnets come together the like
poles push each other away and the unlike poles pull together.
The electromagnets are arranged so that the pushing and pull-
ing of the poles whirls them around and around.

"This is like a generator," Dick observed. Being
asked to explain what he meant, he said that a generator is

1. Parker, Bertha M., "The Book of Electricity." Houghton-
Mifflin Co. 1928.
made of coils of wire and large magnets which are turned in order to generate a current of electricity. A motor is the reverse of a generator.

"What general statement can be made about devices moved by electricity?"

This brought out the idea that everywhere anything is being moved by electricity we can be sure that there are one or more electromagnets present.

"Have we discussed all the ways in which electricity works for us?" I asked as the period ended.

Analysis

The material in this lesson covered more than one period; but, as it was developed continuously, it is written as one lesson. Again the initial question about the electric crane, used to bring out the conception of the electromagnet and its function in electrical appliances, is limited in scope. The same idea could have been developed by ringing an electric bell and developing the question, "Why does the bell ring?"

In discussing the bell, the telegraph set, and the motor, the question in each case is, "What makes it work?" With this practical problem in mind, the examination of these devices is purposeful. What is the function of each part? What relation is there between the parts?
How are all of these devices alike?

The text developed this idea by stating the principle "Wherever you see electricity moving anything, look for an electromagnet." It proceeds by giving examples of devices that contain electromagnets. In our unit, the children develop the idea of finding what makes it work.

The purpose of contrasting the bell, the telegraph, and the motor is to show that each operates on the principle that when an electric current flows through a wire, the wire becomes a magnet and can attract objects and thereby produce motion. The telegraph and the bell produce intermittent or vibrating action because of the springs in their circuits. The motor uses several electromagnets and by changing the poles of the magnets produces a whirling motion.

This lesson could have provided other contrasts by comparing the advantages and disadvantages of these electrical devices with other methods of doing this work. Another contrast could have been brought out between the types of wire used in devices that work on the electromagnet principle and in the devices that produce heat. In failing to bring out these contrasts the ideas presented are not seen in relation to other ideas that are also true.

Perhaps the most pertinent criticism of this lesson is

that the different parts of it are not concerned with solving a central problem but each is centered about a little problem. There was so much stress on finding out how each of the devices work that little time was spent in tying together the threads of thought.

Lesson 8.

The children had been trying to think of other ways in which electricity works for us. Had we talked about all the important uses? We reviewed our discussion by mentioning how electricity makes light and heat, how it moves fans, washing machines, motors, how messages are sent by telegraph. What about other ways of sending messages? Do the telephone and radio use electricity?

To find out how the telephone and the radio work we read the story in our science book.\(^1\) The picture show, "Alexander Graham Bell," was also familiar to a number of the group.

"Did you ever ride along a country road and hear the telephone wires humming?" I asked when the class had finished the story.

Almost everyone had heard this vibration at some time.

"Did you know that this humming is caused by the

\(^1\) Craig and Johnson, "Our Earth and Its Story." Ginn & Co. 1932.
vibration of people's voices traveling along the wire?"

Several people agreed with me but most of the class challenged this statement. Jacqueline was certain that the humming sound is made by the wind blowing through the wires. Jackie had read that people's voices do not travel over the wires—just the electricity goes along the wire.

I was quite surprised at these ideas. How could you hear what people said over the telephone if their voices do not go along the wires? Jackie said that the electricity makes the receiver vibrate and what we hear is the vibrations.

"Anyway," Dick added, "sound doesn't travel fast enough to go over the wires."

The class remembered that it takes sound almost five seconds to travel a mile. If two places were one hundred miles apart, it would take five hundred seconds or almost nine minutes for it to go that far. Does sound travel any faster along wire? Sound travels faster through metals and solids are the best carriers of it. Part of the class still would not agree with me. The sound did not travel along the wire. The sound would have to be very loud, they argued, because soft sounds do not carry very far. They knew that it is unnecessary to raise one's voice when talking over the telephone.

"What happens when you talk into a phone?"

Several of the group contributed a very good explanation
of how a telephone works. I asked the class if this seemed more logical to them than saying that sound waves travel over the telephone wires. We had learned enough about sound in one of our previous units that the class understood the meaning of sound waves and vibrations.

To see just what happens in telephoning, I drew diagrams of the receiver and transmitter on the blackboard. We traced the sound vibration from the time it hits the diaphragm of the transmitter until it is changed back into sound waves by the receiver diaphragm. How is the diaphragm of the transmitter like the key of a telegraph set? This question was asked to bring out the fact that the latter is a device for making and breaking a circuit while the former makes the current first weaker then stronger.

What travels over the wire? How are electrical vibrations turned back into sound waves? Why does the electromagnet make the diaphragm vibrate? These questions brought out the principle of the telephone.

"What did people have to know before the telegraph and the telephone could be invented?"

There were indefinite answers to this question. Electricity. Electricity travels over wire. These were some of the answers. Restating the question by asking what is necessary before a telegraph or a telephone will work brought a better response. Charles said that each one needs
an electromagnet. Without the electromagnet these inventions could not have been made.

The other way to send messages by wire is the radio. I told the class the story about the little boy who asked an aviator if he had ever been up high enough to hear all the messages going out from the radio stations. The aviator said he had not. Why could he not hear the messages? Junior said he would have to have a radio set. Why? So he could pick up the sound waves.

Can sound waves travel far enough and fast enough to be picked up by radio sets? Our knowledge of sound waves led us to believe that the radio picks up some other kind of waves or vibrations. Dick said the radio picks up electrical waves. The aviator could not pick up these waves without a special device.

"What does the radio do when it picks up these waves?"

Observing that we hear sounds over the radio and the radio picks up electrical vibrations, we decided that the radio must transmit the electrical waves into sound waves.

"Is there any difference between time as given over a radio and that of your clock if it is correct?" No, because people set their clocks by the radio. How long does it take electrical vibrations to travel? Evidently they must travel quite rapidly. I told the class they were correct. Electrical waves travel as fast as light waves do—186,000 miles a
second. Listening to a speech broadcast from England we could hear the words of the speaker before the people in the back of the auditorium could.

From these lessons we could understand why electricity is so important to us today and why we feel that we are almost living in another time if we have to do without it.

**Analysis**

The children became interested in finding out how the telephone works through an absurd statement made by the teacher. This absurdity challenged the children to put together the facts that they knew and to see whether or not people's voices cause the wires to hum. The class had to find what actually happens when a telephone is used. The ability to detect faulty reasoning and to sense absurdities is evidence that this is reflection-level thinking.

In solving this problem, the group had to recall how sound travels in order to test whether or not sounds can travel over a telephone wire. If sound waves could not travel over the wire, as the facts indicate, then what does go over the wire? Each question seemed to lead to another one until all the data are in and the problem can be solved.

Comparing the diaphragm of the transmitter with the key of a telegraph set helped to show the relationship between the telephone and the telegraph. The telephone is
seen as one of a group of devices operating on the same principle rather than as a unique device. It is enough different from the other devices that it functions in the desired capacity.

The story about the aviator does the same thing for the question of the radio as the statement about the humming wires did for the telephone. It unsettles the question by introducing a novel situation. Why could not the aviator hear the sound waves? Because he had no radio set? Does a radio set pick up sound waves? If not, why do sounds come out of the radio? These questions required reassembling the data and subsequent re-examination and interpretation of it. This is an illustration of reflection-level thinking.

This lesson successfully promoted a reflective study of the telephone and the radio. Both of these instruments are so common that the children might have assumed that they knew all about them. Using a wrong statement to start the discussion challenged the children and made them realize that there were some inadequacies in their knowledge that needed rounding out before they could prove that they were right.¹ The right-answer technique would have stopped with the first person who said that the wind caused the humming

of the wires. Instead, the class studied the question reflectively, employed a number of scientific principles, and drew their own conclusions.

SUMMARY AND SUGGESTIONS

In developing a reflective study there are certain essentials that must be present in the learning situation. By defining thinking as a process of finding and testing meanings,¹ we assume that thinking takes place in a meaningful situation. A genuine problem must develop within this situation. Solving the problem should require reassembling the data and extracting from them the meaning. As data pertinent to the situation become evident, suggested solutions occur which must be tested in light of the available facts. The learner is responsible for developing his ideas and for reaching conclusions.²

The problem may be a puzzling question, a confused idea, a doubtful issue, or an incomplete situation; but it must be a problem that is real to the children who are to solve it. The teacher who is guiding the study should be skilled in asking questions that raise problems. He should know how to suggest relevant facts, present difficulties, and to appreciate the value of following false trails in order

to make the right one be more convincing.

In criticizing the unit, as a whole, factors that determine how well it succeeds in promoting reflection-level thinking must be taken into account.¹

2. Bruce, Wm., "Principles of Democratic Education."
Prentice-Hall. 1939.

(1) Does a genuine problem exist?
(2) Is the situation meaningful?
(3) Are there several solutions to the problem?
(4) Does the class have the facts in the case?
(5) Is a solution reached that agrees with the facts?
(6) Do the children arrive at their own conclusion?

The unit consists of a group of problems which develop out of a desire to understand the part electricity plays in our lives today. Through meanings obtained in this unit the children should increase in knowledge and understanding of their immediate world as they find out things they do not know and bring their ideas into agreement one with another and with data. The unit does not attempt to teach isolated facts or principles; nor does it cater to immediate interests or whims. The learning, as well as the teaching, is intentional rather than incidental.²

The unit illustrates some of the mistakes that can easily be made, and we have tried to bring out the causes

2. Bruce, Wm., "Principles of Democratic Education."
Prentice-Hall. 1939.
as well as the consequences of these errors. Seeing the wrong thing to do helps in learning what is right; an example of "learning to hit the target by missing it."\(^1\)

The entire unit lacks a definite purpose as far as the children are concerned. The teacher's idea was to study electricity for the purpose of seeing how it works for us. The children were just "studying electricity." They were interested in finding out why we use electricity, what it is, and how it works; but there was no vital reason for them to learn these things. Their knowledge was used in the solution of problems that arose in the course of daily discussions. If the underlying theme had been so broad and so challenging that it was continually recognized as a major problem, the children would have had an end in view which would have added interest and given direction to the series of lessons.

On the other hand, the problems that arose were real problems to these children. They were concerned about finding how electricity is brought to their homes and how electrical appliances are made. Several solutions to these problems were suggested. The children made observations, recalled experiences, and searched for new facts that might help to solve the problem. They drew their own inferences

\(^1\) Bruce, "Wm., "Principles of Democratic Education."

Prentice-Hall. 1939.
and checked the accuracy of their conclusions. A less intelligent or more apathetic group probably would not have responded as adequately to such an indefinite aim as "studying about electricity."

The eight lessons in the unit show a definite pattern. When a genuine problem is raised, the lesson develops in a spontaneous yet orderly fashion. The process of suggesting solutions, marshalling data, testing solutions, and arriving at a conclusion, which are the elements of a reflective study, is used in solving such problems. The thinking does not always proceed in an orthodox manner, but with guidance it eventually reaches a destination.

Lessons three, six and eight are examples of challenging teaching situations. In each of these lessons there is a definite problem: How would you put electricity in a home? How does an electric light work? How do the telephone and radio reproduce sound? Each of these lessons has the essential elements of a reflective study. Actual material is introduced as it is necessary to make the situation meaningful. The facts are used in solving the problem. These minor problems contribute to the solution of the major problem of the unit: How does electricity work for us?

In contrast to these lessons, four, five, and seven, which contain interesting material and have significant conclusions, are not challenging because they lack direction.
The material is interesting but the children do not make any use of it. The weak approach to the problems may probably be the reason for their failure to accomplish much. The children learn some facts but they do not know why they are learning them. They have fun wondering what lightning is; but their learning has no unity. It is not related to other problems of the unit. The problems promote reflective thinking, but they are presented almost as units within themselves. The thought is not connected and the discussion jumps from topic to topic without the smooth transitions that a continuous study should have.

It is impossible to predict just what is going to happen in a classroom because a teacher works with a group of individuals who do not always respond in the expected ways. This is the reason why a lesson planned in detail and faithfully executed becomes autocratic. The teacher should have an idea of what the lesson should include in order to have the class arrive at some conclusion. A reflective study has to be about something, but an attempt to follow a fixed routine or to ask set questions destroys the spontaneity of the situation. The thinking must be pupil-thinking with just enough teacher-guidance to keep the group going in the right direction. The actual teaching must be such as to take advantage of the situations as they arise.

There are some significant outcomes to the unit on
electricity, although the unit does not accomplish all that was expected of it. A wealth of informational material is presented in solving the problems that arise; but never once did anyone complain about having too much to learn. (The term "learn" seemed to be a synonym for "memorize" in this group.) The children were so interested in the problems that arose that the data necessary for solving the problems were seen, not as isolated facts, but in relation to the situation where they are used.

A number of principles about electricity and its use were formulated by the group. Simple inventions which, for a time, seemed to be very complex and mysterious to the group were found to work in accordance with these general principles. The children began to realize that our knowledge has been developed by men who have sought to make the world a better place in which to live. That knowledge is still limited, was another realization.

The children appreciate electricity and our knowledge of it when they try to visualize their world without it. They learned how electricity is made, how it travels to where it is used, why it should be controlled and how it is controlled. By examining electrical appliances they formulate the principles employed in making them work. The conclusions came at the end of the study of the problems as a
result of reflective thinking about these problems.¹

CHAPTER II

A UNIT ON ELEMENTARY CHEMISTRY

Lesson 1.

This unit developed from a real desire of the pupils to know something about chemistry. May we study about chemistry? May I bring my chemistry set to school? Will you do some experiments for us? What does a chemist do? These questions indicate that chemistry is a new field of interest for the class.

The children knew that we were going to study about chemistry. When they were in their places, I took a rock from the collection on the science table. I could tell from the expression on the children's faces that most of them were thinking, "What does a rock have to do with chemistry?"

"What would you like to know about this rock?" I asked.

What kind is it? Where did you get it? What is it made of? From these questions the class realized that, although they knew that rock is called quartz and that Janice brought it from Colorado, they did not know what it is made of. Blossom volunteered that she had always wondered how you can find out what things are made of "if you don't already know."

I said that, long ago, people had asked this question, "What are things made of?" A Greek, who lived
nearly twenty-five hundred years ago, thought everything in the world was made of air. He said that when air became thinner it turned into fire and when it became denser it formed water. He also thought that water could change into earth.

The children were quite amused that anyone could be so foolish as to believe that everything is made of air.

"Doesn't water disappear from the earth and go into the air?"

"That's true," said Marie, "but water doesn't change into air; it evaporates."

The belief of the Greek, however, did not seem so unreasonable when the class realized that, long ago, people did not know about evaporation and condensation. Famous scientists did not know things about the earth that a ten-year old boy knows today.

"Later on the Greeks decided that everything in the world was made of air, water, soil, and fire," I told the class. "Would you agree with this explanation?"

The class did not agree. I told them that since living things need air and water to grow, the scientists had decided that many things must have air and water in them. There must be soil in all living things because plants grow out of the soil and animals live on plants. This explanation began to seem plausible to some of the children.
"But what about fire?" they asked.

"Since fire comes out of things when they burn, the wise man decided that there must be fire in everything."

Some of the class were almost convinced that everything is made of these four things. Fortunately, there were still a number of skeptics.

"What about rocks?" they asked.

"Scientists said that all solid things were made of earth. Surely you remember how sedimentary rocks are made?"

"How can volcanic rocks be made of earth?"

"Are people made of earth?"

After this introduction, the group was determined to find out what things are made of, or at least to prove that everything is not made of air, water, fire, and earth. They decided that the best way to do this would be to examine and compare some common materials. They made a list of materials and saw that each material may be described in a different way. The words that describe a material are characteristics. Every kind of material has characteristics of its own.

The children volunteered to bring different materials to school. Jacqueline suggested that we ask each person questions to find out what material they had brought. Some of the questions we should ask were: How does the material feel? What color is it? Is it transparent? "Will it melt?"
Does it smell? (We decided that this question should be--
Does it have an odor?) Is it a solid, a liquid, or a gas?

At the close of the period, I referred to the idea
that everything is made of air, water, fire, or earth. Most
of the class agreed that this idea seemed rather improbable
but that we had not yet found out what things are made of.

Lesson 2.

This period was devoted to a discussion of character­
istics of materials. Each child brought a material and was
given an opportunity to answer questions about it. The per­
son who guessed the name of the material became the next
leader. The class tried to ask questions that would give
clues about the material.

By the end of the period, we could see that the char­
acteristics of a material not only tell what kind of a mater­
ial it is, but also what use is made of it. When the ques­
tion "Is it used for windows?" was asked, the leader laughed
because he had a piece of iron.

"Why did Donald laugh?" I asked.

"Iron isn't transparent," answered Beverley. "You
want to see through windows."

The class realized that it is important to know the
characteristics of a material before trying to use it. Lead
would be a poor material for a stove because it melts too
easily. A wooden stove would burn if a fire were built in it. Cellophane is better than tissue paper for wrapping food.

Another question that raised a problem was, "How does it taste?"

The objection to this was that some material cannot be tasted. Dick said that you should never taste a material unless you know what it is. It might be poisonous.

Zelina said that the only way to tell if a liquid is sour is to taste it. Vinegar is sour. If tasting a material is dangerous, how can you find out if it is sour? Dirk said that it can be tested with litmus-paper. Vinegar will turn a piece of blue litmus-paper red. He did not know why.

We decided to test some other liquids with litmus-paper. We used sweet milk, sour milk, vinegar, a lemon, a solution of sugar, a tomato, a baking soda solution, and hydrochloric acid. Everything that is sour changed the color of the litmus-paper from blue to red. The class decided that using litmus-paper is a safe test for sourness. I told them that everything that is sour contains acid.

Marie was curious about the sweet and sour milk. She knew that sweet milk turned sour. When this happened did the characteristics of the milk change? Would it still be the same material?

Here was a problem. Can characteristics be changed?
Do these changes make new materials? I asked the class to try to recall times when they had observed changes taking place in materials.

Lesson 3.

"Did you notice any changes in the characteristics of materials?" I asked the class at the beginning of the period.

Water changes into ice. Ice and snow melt and make water. Water evaporates. Sugar and salt dissolve in water. From these illustrations, the children saw that characteristics of materials can be changed. But are new materials made?

"Ice isn't the same material as water."

But ice melts and becomes water again. Melted butter solidifies when put into the ice-box. A sugar solution still tastes sweet and a salt solution is still salty. The group decided that some of the characteristics of a material can be changed without producing a new material.

Before anyone could ask about the souring of milk, I told the children I would do an experiment for them so they could see characteristics change. I heated some sugar in a test-tube. As the children watched, they saw the sugar change in color from white to black. A white gas filled the test-tube and several drops of a brown liquid collected in the tube.
"What has happened?" I asked.

The sugar melted; the sugar burnt; the characteristics changed, were some of the answers.

"Is the material still sugar?"

If it is still sugar it should taste sweet. It tasted bitter. It not only looked like a different substance, but it tasted like one.

I asked the class if they had ever seen an old can that has been left outside for a long time. Of course they had. Anything made of iron or steel rusts when it is left outdoors. "The rain rusts them." Rust changes bright, shiny things to brown and crumbly ones. If they get rusty enough, they fall to pieces.

"But we said that materials cannot be changed," James objected.

"Are burned sugar and rust new materials?" I asked.

The class agreed that they are certainly much different materials. Dick decided that we were wrong in saying that a change in characteristics does not make a new material. What about the sugar solution and the melted butter? Carol thought there must be two kinds of changes—the kind where a new material is made and the kind where the material does not change. According to the evidence, this seemed to be a logical conclusion. I told them that changing the form of a material from solid to liquid or gas and dissolving
a material does not make new materials. These are physical changes. A change of characteristics in which a new material is made is called a chemical change.

"Are we studying chemistry?" Mason wanted to know.

"What do you think?" I asked him.

Jackie suggested that we look up the definition of chemistry. "Why that's just what we're doing!" he exclaimed when he found the definition.

Several other chemical changes were discussed. Some of these were burning, decay, leaves changing color, and digestion.

Lesson 4.

"When are we going to find out what things are made of?" asked Howard, as the discussion period opened.

We had seen that all materials have characteristics and that these characteristics may be changed.

"What is sugar made of?" I asked.

The idea of sugar being made of anything had never occurred to the children. Sugar is just sugar. The class giggled when I asked if they thought sugar is made of air, water, soil, or fire. I told them that the scientist who believed this had called these four substances "elements."

"Why did he call them elements?" Jack asked.

Our dictionary gave us this definition; an element is
the simplest kind of material. It cannot be separated into any other materials. The children immediately realized that air cannot be an element because it is a mixture of oxygen, nitrogen, and carbon dioxide. Water is made of hydrogen and oxygen. The decision of the scientist had seemed reasonable because he did not know the composition of air, water, and earth.

"If air, water, fire, and soil are not elements, can you name any materials that are elements?" I asked.

After a long list of materials had been named, I asked of there is a way of finding whether these materials are all elements. Among the materials that had been named were a number of compounds.

Dick suggested that we try to find a list of the names of elements. Billy thought that such a list would be so long that it would not be found in any of our books. Since we did not have a chemistry book, we referred to the "World Book." Here we found that there are only ninety-two known elements. By checking our list we also discovered that such things as sugar, salt, alcohol, vinegar, and brass are not listed as elements.

Some of the elements were quite familiar. Most of the children had seen copper, silver, lead, zinc, aluminum, mercury, carbon, tungsten, and nickel. A question arose as to why they had never seen or heard of so many of the
elements. Examining the list they found the ones that are never seen are either colorless gases or very rare elements.

"Why does it say 'known' elements?" asked Jackie.

"Because scientists think that there are more to be discovered," explained Dirk.

"Do you think that sugar is an element?"

"It isn't in the list of elements," answered Charles.

"Can you think of any way to prove that it isn't an element?"

We referred to the definition of an element and decided that if a material is not an element more than one material will be found in it. Dick suggested that we try to take the material apart. Finally the class recalled that we had changed sugar by heating it. The experiment was repeated and we observed that a brown liquid and a white gas are formed. Here were two other materials; apparently sugar is not an element because it contains more than one material.

I told the group that sugar is a compound made of three elements—carbon, hydrogen, and oxygen. Our dictionary said that a compound is made of two or more elements joined together.

The answer to our question, "What are things made of?" apparently was, "They are made of elements."

"Don't you have to know what elements they are made of?" asked Billy.
Dirk volunteered that chemists are men who analyze materials and determine their composition.

"Why do people study chemistry?" I asked as the period ended.

Lesson 5.

Some elements had been collected by the children for the science table. The collection included a piece of iron, a copper penny, a nickel, a piece of tungsten wire, the zinc cup and carbon rod from a dry cell, some powdered sulphur, a lead shot, an aluminum pan, a gold ring, and a silver bracelet.

I asked the question of the preceding lesson, "Why do people study chemistry?"

None of the answers was very definite. Someone thought that chemists are curious to know what is in things. They want to make new things--these were some of the answers. Dirk said that chemists experiment to find how chemicals react when put together.

"Are we any better off for knowing these things?" I asked.

Most of the group thought that the chemist does many things that help us. By studying materials he can find those which have useful characteristics. He can make new materials that we need.
"How can new materials be made?"

A change in which a new material is made is called a chemical change. New materials are made by putting elements together because elements themselves cannot be changed.

"Would you like to make a new material?"

The group was delighted. I mixed powdered sulphur with iron filings. The children were disappointed because the "new" material did not look interesting.

"Is this a new material?"

The class was rather undecided about this. They reminded me that I had promised to make a new material and that two elements had been mixed together. If this material was a new material then the characteristics of iron and sulphur would be changed. Tests, however, showed that the iron filings could be separated from the sulphur with a magnet. When water was poured on the mixture, the sulphur floated to the top while the iron remained at the bottom. We decided that, although two elements had been mixed, a new material or compound had not been formed.

I suggested that the mixture be heated. When the iron and sulphur became very hot they seemed to melt and run together. A distinct odor was also noted. We had to break the test-tube to remove the material. The tests for iron and sulphur gave no results. A compound with characteristics different from those of either iron or sulphur had been
formed.

In trying to find out why it was necessary to heat the iron and sulphur to make a new material, the children observed that the two materials seemed to "go together" when they were heated. The definition of a compound, a material made of two or more elements joined together, told us that the elements actually unite. The materials in a mixture keep their identity. The material we had made was a compound of iron and sulphur called iron sulfide.

After observing this chemical change, the class could understand how carbon, oxygen, and hydrogen—a black material and two odorless gases—can make white, sweet sugar. Water is made of two gases, oxygen and hydrogen. In each compound the elements have united to form a different material. Other compounds such as salt, white paint, red lead paint, and carbon dioxide were mentioned. The children were interested in finding out why salt, made of a poisonous element, chlorine, and an element that will burn, sodium, neither burns nor is poisonous. Characteristics of sodium and chlorine disappear when the new material is formed.

"Suppose that a material is heated and no change takes place. Is this proof that the material is an element?"

This question led to a discussion of ways of testing whether materials are elements or compounds. The class decided that, since heating does not change such compounds
as water, materials should be tested in several ways.

I asked Marie if she could answer her question about the souring of milk. Are sweet and sour milk different materials? If souring forms a new material, then it is a chemical change. After comparing the characteristics of the two, Marie decided that a chemical change takes place when milk sours.

After this discussion, the children began to understand that chemical changes are happening all around them. The chemist studies and experiments in order that he may learn how to make new materials.

Lesson 6.

Continuing the discussion of chemical change, we took up the question, "What does the chemist do to help us?"

"How long has glass been used for window panes?" I asked.

Blossom said, "It wasn't used in pioneer times because people put oiled paper in the windows of their cabins."

"They used oiled paper because they lived too far away from the places where glass was made," added Carol.

"How is glass made?"

Jackie thought that it is made from sand. Dick said that the sand had to be melted in a furnace. We read about glass in the reference book and found that it is made by
mixing soda ash, sodium carbonate, or sodium sulphate, limestone, and sand and heating the mixture until it melts to a clear mass.

"Why that's a chemical change!" exclaimed Jackie.

(Later the children would learn that glass itself is not a true chemical compound.

The children were eager to know more about glass-making. Who discovered how to make glass? How is bullet-proof glass made? What kind of sand is used? How can colored glass be made? What is pyrex? In reading to answer these questions, they found that, although glass-making began several thousand years ago, it is due to the work of the chemist that glass is so useful to us today.

The class was interested in finding other materials that chemists have helped to make. Paper, rayon, nylon, steel, plastics such as bakelite, ink, dyes, paints, varnish, and explosives are all made by chemical changes. In telling about each material, we listed characteristics that make it more useful than the materials from which it is made. It was quite easy to see that a piece of wood could not be used for dresses or books as rayon and paper can.

"Are there any other uses of chemical changes?"

Receiving no answer, I asked Charles how his house is heated in winter. He replied that it is heated with a furnace that burns coal. As burning is a chemical change, we
can say that chemical changes are used to produce heat.

Marian added that we use heat to cook our food. At this point, Howard wanted to know if cooking is a chemical change.

"What happens when food is cooked?"

It tastes better, digests more rapidly, becomes softer were some of the answers. Ruth Mary said that a cake rises when it is baked. In answer to the question, "Why does a cake rise?" the ingredients used in a cake were named. Marie said that the baking-powder makes the cake light. Ruth Mary looked up the composition of baking-powder and found it brings about a chemical change that makes the cake light.

Why is soda used in place of baking-powder when sour milk is used? The solution to this problem appears to lie in the difference between sweet and sour milk. When soda was added to the sour milk, the children saw that it reacted vigorously giving off carbon dioxide. The milk was tested for acidity. The children found that it neither tested sour nor changed the color of blue litmus-paper. The baking-soda had brought about a chemical change.

Lesson 7.

"We have been discussing how chemical changes make new materials and produce heat. Can we say that all chemical
changes are helpful?"

A number of the group thought that all chemical changes are useful. If any were harmful we would be trying to prevent them instead of helping them take place.

"Sometimes milk sours when we don’t want it to," James objected.

"Burning isn’t always helpful," was another objection. "Fires do a lot of damage."

Some chemical changes must be harmful. Rusting of metals, fading of cloth and paper, spoiling of foods, and decaying of wood were examples of destructive changes. Two questions arose from this discussion. Why are these changes harmful? Can they be prevented?

The changes are harmful when they destroy useful materials. Burning is helpful as long as it produces heat that we can use, but when it destroys buildings and forests it is harmful. The children were unable to think of any times when rusting and fading might be useful changes.

"Can rusting be prevented?"

At first no one could think of any way to prevent rust from forming. Then Leiland remembered that tools are greased to keep them from rusting. Automobiles and bridges do not rust because they are painted.

"Why does paint or grease keep iron from rusting?"

Obviously to answer this question we needed to know
what happens when iron rusts. Rust is a new material which is formed when iron is left outdoors. What unites with the iron? Apparently one of the materials in the air unites with the iron. Billy thought rain causes rust because when his skates got wet they rusted. Our reference book said that the oxygen in the air combines with the iron forming rust.

"What will keep iron from rusting?"

"Keep the oxygen away from the iron," was Mary's reply. "That's what paint and grease do."

"Suppose a fire started in our wastepaper basket. What would you do?"

Get some water, use the fire extinguisher, stamp on it, throw a coat over it, smother it were some of the suggestions.

"Why does water put out a fire?" I asked.

Jack said, "It cools the fire."

"Does the same thing happen when a coat is thrown on the fire?"

"No, a coat smothers the fire," answered Billy.

"Fire needs air to burn," Marie observed.

I told the children to watch an experiment that I was going to do. I put an empty milk bottle over a lighted candle. The candle went out in a few seconds. Then I put a lighted match into the bottle. The match also went out.
"What happened?" I asked.

Anita thought that the candle had used all the air. Ruth Mary objected to this explanation. She said that only oxygen is used in burning and this is just one-fifth of the air. Asked to prove her statement, she told of a similar experiment used to demonstrate air pressure. The candle is placed in a pan of water and when the flame goes out the water rises about one-fifth of the way into the bottle.

Anything that keeps the burning material away from oxygen will put out a fire.

I put some baking-soda in a test-tube and poured vinegar on it. Then I held a lighted match over the test-tube.

"Why does the match go out?" I asked.

Dirk said that the vinegar reacts with the soda giving off carbon dioxide. Does the carbon dioxide put out the flame? Howard said that carbon dioxide is a heavy gas. It acts just like water and keeps oxygen away from a fire. A fire extinguisher works on this principle.

One way of preventing harmful chemical changes is to keep apart elements that will combine.

Cooling milk and foods that will spoil is another method of preventing chemical changes. Rust and decay occur more rapidly when materials are wet so some chemical changes can be prevented by keeping materials dry. Materials that fade should be kept out of the sunlight. Members of the
class told of chemical changes they had helped to prevent.

Resume

The introduction of this unit was a question concerning the composition of materials. In an attempt to answer this question, the theories propounded by Greek scientists that everything is made of air, or of air, water, fire, and soil, were introduced. No one took these theories very seriously although reasons why they might be true were cited. It was decided that the question might best be answered by examining some common materials. As these materials were described, the term "characteristics" was used to apply to the words and phrases that tell about the material. Characteristics also determine the use of materials.

The study of characteristics of materials led to the question of whether characteristics can be changed. After finding that some of the characteristics can be changed, the question arose as to whether new materials are made by these changes. The final decision was that there are two kinds of changes: one in which some of the characteristics change but the material does not lose its identity is a physical change. The other change is the formation of an entirely new material with different characteristics and is called a chemical change.

Before the idea of what happens during a chemical
change could be developed further, it was necessary to go back to the question of the composition of materials. From the definition of an element, the fallacy of believing that all things could be made of one material or even of four materials is seen. An experiment with sugar brings out the idea of a compound. That compounds are made only when elements actually unite was shown by contrasting the results of mixing iron and sulphur and of heating this mixture. New materials made by chemical changes have characteristics that are entirely different from their components. This is the reason why common materials, such as glass, paper, and rayon, are more useful than the sand and wood from which they are made. Changes that occur during cooking of foods and the production of heat by burning are other useful chemical changes.

By raising the question, "Are all chemical changes useful?" the contrast between helpful and harmful chemical changes is shown. Harmful changes are considered as to why they are harmful and how they can be prevented or controlled.
ANALYSIS OF UNIT

In analyzing the lesson of this unit, each phase of developing a reflective study of chemical changes is considered.

(1) Is the situation meaningful?

The problems which are developed in the unit grow from the children's desire to know more about the materials in their world. The situation is familiar and of immediate interest to them.

(2) Do genuine problems develop within the situation?

Five of the seven discussion lessons develop genuine problems:

Lesson 1. What are things made of?
Lesson 3. Do materials lose their identity when their characteristics change?
Lesson 5. How are new materials made?
Lesson 6. What does the chemist do to help us?

(3) Are there several solutions to the problem?

Each of the problems has several suggested solutions:

1. What are things made of?
   a. All things are made of air.
   b. All things are made of air, water, soil, and fire.
   c. All things are made of elements.
2. Do materials lose their identity when their characteristics change?
   a. Materials do not change.
   b. There are two kinds of changes.

3. How are new materials made?
   a. Elements are mixed.
   b. Elements unite.

4. Why do people study chemistry?
   a. They wish to find out about elements.
   b. They want to analyze compounds.
   c. They are trying to make new compounds.

5. Are all chemical changes helpful?
   a. All chemical changes are helpful.
   b. Some chemical changes are harmful.
   c. Chemical changes may be either helpful or harmful.

(4) Are data collected and observations made which will help in solving the problem?

The children collect their data by reading for special purposes such as to find the names of the elements or to see how a chemist makes new materials. The experiments used in the unit lead to needed observations. The children recall the data they have previously observed or read about and apply these facts in testing the suggested answers to the problems.
(5) Do the children arrive at conclusions which agree with the data?

After examining the evidence, the group reached these conclusions:

1. All things are made of elements.
2. There are two kinds of changes—physical and chemical.
3. When elements unite, new materials are made.
4. There are many reasons why people study chemistry. The most important are to find new uses for materials and to make new materials.
5. Chemical changes may be either helpful or harmful.

These conclusions agreed with the data collected by the group and were their own solutions to the problem.

Perhaps the reader has observed that this unit lacks the spontaneity and force of the previous unit on electricity. There is no real problem in this unit in the nature of a conflict to be resolved. The children wanted to study chemistry because a number of them had chemistry sets. In order to start the study, a problem is manufactured. This is a very poor teaching device. If a real problem does not exist, if there is no particular reason for starting a study, then the matter had best be left untaught.

This difficulty is encountered when an attempt is made to teach subjects. The same difficulty is found in the unit
method if the unit does not represent a reflective study of challenging problems. This is the reason curriculum makers have set up a core curriculum which cuts across subject-matter lines and bases instruction on social functions or social problems. It is an attempt to make the situation meaningful. ¹

A unit on chemistry must, of course, include a study of elements and compounds. An elaborate device is employed to be sure that they are included in the discussion. One of the criticisms that may be made of science courses in general is that instructors look upon science as organized and tested knowledge rather than as a method of obtaining knowledge. ² Courses are organized about things that "have to be taught." The use of artificial devices to arouse interest and stimulate discussion does not make a situation as meaningful as it ought to be.

SUMMARY AND SUGGESTIONS

The purpose of the unit was to develop a reflective study of chemical changes in order that the class might appreciate more fully the work of chemists and the function of chemistry in everyday life. The unit was planned to include a number of activities that would satisfy the children's

2. Ibid.
wishes to experiment and would also develop their understanding of chemical change.

The text starts the discussion by telling the story of the scientist who thought that everything was made of air, water, fire, and soil. Instead of letting the pupils wonder if this is true and search for data to prove or disprove it, the text immediately says that this is not true. No conflict is raised and part of the incentive to search for material is gone.

The activity of collecting and examining materials raises questions and opens the way to answer them through experimentation and observation. In both the text and class presentation, purely recollection-level and recognition-level thinking were used in the discussion of the characteristics of materials. There was no attempt to answer the problem raised in the first lesson or to test the theory presented there about the composition of materials. This was inconsistent with the plan of the unit which was to develop first the idea of the scientist's knowledge of the structure of matter and then bring out the importance of this knowledge.

Many of the questions might have been developed by reflective study. If the question, "How does it taste?" had been so worded that it asked how you can find out if a

a liquid is sour, there would have been a choice of answers from which the children could have chosen the best one. As it was, only recognition-level thinking was needed to apply the knowledge that the vinegar will change the color of blue litmus-paper, to the use of litmus-paper as a test for acidity.

The discussion does lead to the question of whether the characteristics of a material can be changed. The text makes the statement that there are two kinds of changes in materials and describes these changes. By letting the class believe that materials cannot be completely changed and then doing the experiment with sugar which indicated that a new material had been made, the group is led to decide for itself that there are two kinds of changes. From this decision they formulated the definition of chemistry and chemical change which was meaningful to them because it grew out of their immediate experience.

After the discussion of characteristics of materials and changes in characteristics, in the next lesson we presented the term "element" and tested the theory that all things are made of four elements. Presenting the term before the meaning was established gave little opportunity for reflective thinking.

In contrast, we developed the meaning of compound through the experiment with sugar. To test the theory that sugar is an element, the sugar was heated and more than one material was found to be present. In this way the idea of a compound was developed. When the children actually saw the white, sweet sugar break down into several materials, they began to realize that "things are not always what they seem."

The question of compounds was quite fascinating and let to a discussion of how a chemist makes new materials. The introductory question for the next lesson, "Why do people study chemistry?" has wide and practical implications but it was dropped as soon as new materials were mentioned.

The procedure of letting the class follow a false trail was used in the experiment with the iron and sulphur. The children thought a new material was being made. When the characteristics of iron and sulphur were not changed, they realized that something was wrong. By comparing the result of the experiment with that of heating iron and sulphur, they began to understand the difference between a mixture and a compound.

The text introduced this same idea by the statement:

"Whenever compounds are made, the elements do not just mix"

with each other. "They unite, or join, with each other to form the compound." The experiments are used to corroborate this statement. In a reflective study the conclusion comes at the close of the two experiments and is formulated by the children.

In place of the question, "How do we use chemical changes?" as developed in the text, the following lesson was introduced by the questions, "What does the chemist do to help us?" The study of glass-making brought out the idea that a chemical change makes a material like sand more useful. Chemistry becomes more closely associated with everyday life when the children realize that a chemical change, burning, produces heat and cooks their food.

Recognition-level thinking was employed in answering the questions about the chemical change caused by using baking-powder in cakes. This might have been developed as a reflective study if an actual experiment with baking-powder had been performed and if thought-provoking questions had been asked.

The text introduces the idea of harmful chemical changes by stating that some changes are harmful and then listing methods of controlling or preventing such changes. In introducing the problem in a reflective study, harmful changes were contrasted with helpful changes. The statement that all changes are helpful challenged the class to find
exceptions to it and brought forth such problems as, "When are chemical changes harmful? Can harmful changes be prevented?"

The data used in solving these problems included the cause of the harmful change and the materials which unite to form a new substance. The children already knew how to control rusting and burning but they did not understand how paint prevents rusting or why water puts out a fire. In each case the children made their own decisions why particular methods are used to prevent the chemical change.

As the analysis indicates, this unit has many of the characteristics of a good reflective study although it lacks the spontaneity of the unit on electricity. If the study had grown out of a genuine problem that challenged independent thinking, the response would have been far more enthusiastic, as well as educative.\(^1\) The difficulty lay in the fact that the question, "What are things made of?" did not unsettle previously fixed ideas in the minds of the group. There was no conflict, and the class was only mildly interested in the problem. They were rather complacent about their knowledge, and wanted to play with the chemicals in the chemistry sets.

An experiment which showed a chemical change taking place, the question of what happened to cause the change, or several conflicting theories as to the nature of the change would possibly have been more effective in setting up a

\(^1\) Dewey, John, "Democracy and Education." Macmillan. 1916.
challenging situation. An explosion might have been used as an example of a chemical change. In discussing what happened, the idea of materials being made of several elements could have been brought out. Elements and compounds would then derive their meaning from this situation within the personal experience of the class. This brings out the difference between a genuine problem and one simulated for the purpose of conveying information about chemistry. A genuine problem is a pupil-problem rather than a textbook or teacher problem.¹

CHAPTER III

A UNIT ON FIRE CONTROL

The third unit in this series grew out of a discussion of how to put out a fire in the unit on chemical changes. The class was quite satisfied with the explanation that a fire can be extinguished by using water or sand to "smother it." I suggested that we have a demonstration of building and putting out a fire in a safe spot on the school ground.

The results of this demonstration were very poor as far as pupil satisfaction was concerned. The ground was damp; a quantity of matches were consumed before the paper used as kindling would ignite; and the paper burnt so quickly that the larger pieces of wood only charred. The class was determined to find out what was wrong with their fire-building and to try again.

Back in the classroom, I asked what is needed for a fire. We finally decided that a material that will burn is the first necessity. Would not paper and wood do for a fire? The paper burnt too rapidly and the large pieces of wood too slowly. Dick suggested that some small pieces of kindling were needed. From this discussion the terms combustible material, high and low kindling temperatures developed. Did we need to use so many matches? What had people used to light fires before there were matches? Fire by friction was
discussed and matches were seen to be another example of fire by friction. Charles thought if we lighted the fire on the side toward the wind the matches would not go out so quickly.

The next day we tried the demonstration again. This time we were more successful; but the larger pieces of wood did not burn very long. The fire was easily extinguished with water and sand was thrown over the ashes.

As the class was still dissatisfied with their efforts, I showed them how candles will burn in a lamp chimney. First, I put a glass cover over the chimney and the candles went out. Corel suggested that I take off the glass cover so the candles could get some air. The candles still went out. What was wrong? A kerosene lamp burns with a chimney. Since I had a combustible material (the candle), burning evidently required something else. This "something" was a current of air we decided when the candles burnt after the chimney was raised by putting lead pencils under it. The burner on a kerosene lamp was seen to have air holes at the bottom. Billy explained that our camp fire did not burn well because the sticks could not get enough air.

Why does burning require air? Ruth Mary said that the oxygen in the air unites with the material causing a new material to be formed. Could she prove this? Several ways of proving it were suggested. Two of them were trying to
burn a match in each one of the gases composing the air and removing the oxygen and seeing if a match would burn in the remaining gas. The latter method, we decided, would be the easier. How to remove the oxygen was another question.

Remembering that iron combines with oxygen when it rusts, we shook iron filings in a damp test-tube and inverted the tube in a pan of water. The next day, the iron filings had rusted and the water had risen in the test-tube indicating that a gas in the air had combined with the iron. We found that the remaining gas would not support combustion. Here the question was raised—was the failure to support combustion due to the lack of oxygen or the narrowness of the tube? The test was repeated with a burning match in a similar tube. Since the match did not go out at once, we decided that the narrow tube was not the reason why the first match went out.

Marie wanted to know just why oxygen is necessary to keep a match burning. Does the oxygen burn? We decided to observe a fire and see what happens when materials burn. Perhaps our observations would help answer Marie's question. Watching the fire, the class noticed that heat is given off, a light can be seen, and the material burning becomes smaller. It was evident from these answers that the material changes. We concluded that the material must unite with the oxygen to form a new material.
Why does a candle disappear when it burns if a new material is formed? If it unites with oxygen, why cannot we see the new material? We learned that a candle is composed of two elements, carbon and hydrogen, united in the compound paraffin. We lighted the candle and then blew it out. We noticed a white gas was given off at the wick. When a burning match was held above the wick, the wick caught fire. The class decided that the paraffin first changes to a liquid and then to a gas. The gas must contain both carbon and hydrogen. A cold saucer when held in the candle flame became black. The saucer cooled the carbon so that it did not burn. Tests with limewater showed that the carbon unites with the oxygen, as it burns, and makes carbon dioxide.

To see what happens when the hydrogen burns, a cold glass jar was inverted over the candle. A film of moisture on the sides of the jar appeared. We concluded from this that the hydrogen unites with oxygen forming water. The reason the candle disappears when it burns is that it changes to colorless gases as it unites with the oxygen.

From additional reading we learned that all fuels contain carbon and hydrogen so carbon dioxide and water vapor are universal products of burning. When a fuel burns it changes to two colorless gases.

What if all of the material does not burn? What are ashes? What is smoke? These questions from the students
who were unwilling to accept the conclusion unsettled the issue again. Do all burning materials give off smoke? Why is some smoke black and heavy while other smoke is white and gray? Why did our outdoor fire smoke? Ashes must be the part of the fuel that is not changed into a gas or the minerals.

Jack said that our fire smoked because the wood was damp. If the fuel is damp it does not burn readily. This is because the material is not hot enough. Smoke, then, is given off when the gases are not heated to their burning temperature.

Why does a stove smoke when the damper is turned off? Why does it smoke when more fuel is added to the fire? Since the damper and the extra fuel both shut off the supply of air, we decided that lack of oxygen will also cause a fire to smoke. Very black smoke must contain a great deal of unburned carbon.

The next question was why are water and sand or dirt used to extinguish fires. They "smother" the fire was the reply. Smothering was defined as keeping away the air. Of course, if oxygen is one of the things necessary for a fire, lack of it causes the fire to go out. Can big fires be controlled by cutting off the oxygen supply? Could a forest fire or a prairie fire be extinguished with water? Methods used by fire fighters were discussed. Fire lanes,
back fires, and blowing up large buildings in a fire zone prevent fires from spreading by clearing away combustible materials from the path of the fire.

Can we say that water is the best fire extinguisher? Most of the class thought this is true because water not only shuts off the supply of oxygen but also cools the burning material below its kindling temperature.

If the grease in a fire pan catches on fire, would you pour water on it? Here there was a difference of opinions. Several of the class objected rather violently. Water, they said, will spread the fire. Why? No one knew but they were positive that water cannot be used. I mixed some water and kerosene together and let it stand. The oil floated on the top of the water. Water spreads a kerosene or gasoline fire because it floats these lighter liquids.

What can be used to put out an oil fire? Sand or dirt can be used. Another suggestion was a fire extinguisher. How does a fire extinguisher work? Mary thought that if it contained water it would not put out an oil fire. Billy said people carry fire extinguishers in their cars to put out gasoline fires. Does a fire extinguisher have water in it? We investigated and found that all fire extinguishers are not alike. The one in our hall is a carbon dioxide fire extinguisher. Why does it have to be turned upside down? Someone insisted that it hung upside down. We
answered this question when we saw that an acid mixes with a chemical dissolved in the water when the extinguisher is inverted. This makes carbon dioxide gas which forces the water out on the fire. The water and gas put out the fire. We concluded that our fire extinguisher cannot be used to put out an oil fire.

Another type of a fire extinguisher is one that contains a chemical called carbon tetrachloride which changes to a gas when it gets hot. This gas is about five times as heavy as air; so it settles, covers the fire, and keeps the air away. Bruce said this must be the kind people carry in their automobiles. Mary added that there are three kinds of materials that will put out fires—liquids, solids, and gases.

After this discussion a list of safety rules to prevent fires was made by the class. These rules were derived from the information that the group had obtained during the study of fire control.
ANALYSIS OF UNIT

(1) Is the situation meaningful?

The problem of how to build and to extinguish fires is quite within the children's field of experience. The group knew how to put out a fire but they did not understand the principles involved in fire control. They had been cautioned about playing with matches and setting fires so much that most of them were afraid of fire.

(2) Do genuine problems develop within the situation?

The problems that developed were mostly of the "why" type.

1. Why did not the large sticks of wood burn?
2. Why is oxygen necessary for a fire?
3. What happens when a material burns?
4. Why does a candle disappear when it burns?
5. Why do some fires smoke?
6. Why does water put out fire?
7. How does a fire extinguisher work?

(3) Are there several solutions to the problem?

Very few of these problems had several solutions. The fault seems to lie in the way the questions are stated and in the haste to cover the material in the class discussion. Such a question as "Why is oxygen necessary to fire?" assumed that oxygen is necessary and was answered by observing what happens when a material burns.
If the class had been led to give several solutions to the problem such as "oxygen unites with the material," "oxygen helps the material to burn," "oxygen catches on fire," these solutions could have been tested by observation and investigation. Failure to develop forked-road situations is the great weakness of this unit and keeps it from being a good reflective study.

(4) Are data collected and observations made which will help in solving the problem?

The data used in answering the questions were collected by experimentation. The experiments led to observations and further questions. These experiments included:

1. Building a fire which did not burn. This led to the question, "What materials and conditions are necessary for a good fire?"

2. Lighting the candles in a chimney. This brought out the need of a current of air and the question, "Why does a fire need air?"

3. Removing the oxygen from the air in a test tube by letting iron rust in it and showing that a match will not burn in the test tube. This proved that oxygen is the element in the air essential for combustion.

4. Burning a candle and testing the products of combustion. This brought out observations of what
happens when paraffin burns and when other fuels burn.

5. Reading and examination of diagrams of a fire extinguisher. These methods were used to show that all fire extinguishers are not alike.

(5) Do the children arrive at conclusions which agree with the data?

When children do not see all sides of a question and are not faced with choosing the best solution from several that sound as if they might do, then arriving at the right conclusions is easy. The children reached conclusions that agreed with the data, it is true, but such conclusions were quite evident in view of the limitations of the discussion and data. Several of the conclusions had already been stated in the preceding unit on chemistry.

These conclusions are:

1. A fire requires a combustible material, a material with a low kindling temperature, and a current of air.

2. The oxygen of the air combines with the fuel and forms two colorless gases. Heat and light are given off as the materials burn.

3. Fires can be extinguished by removing the combustible materials, by cooling the materials below their kindling temperature, and by shutting off the
supply of oxygen.

4. Since water spreads an oil fire, there are two types of fire extinguishers.

**SUMMARY AND SUGGESTIONS**

The problem of how we control fire was introduced by building a fire which did not burn in order to raise the question of what is needed for a fire. The text introduces the unit with a description of a Boy Scout troop building a fire. Building a furnace fire is described and the question of what is necessary to build a fire is asked. The children who read the story merely need to recall the things previously mentioned to answer this question.

The statement that a supply of fresh air is needed to start a fire and keep it burning is made and proved by the experiment with the candles and the lamp chimney. Showing that the candles will not burn unless the air goes in under the chimney is not an effective method of developing reflective thinking. The illustration shows just what is going to happen.

Instead of continuing with the question of why air is necessary for burning, the text introduces the question, "How do we light fires?" and answers it by a discussion of fire.

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by friction and matches. Then the question, "What happens when things burn?" is asked and answered immediately. Letting the children make these observations for themselves raises the type of thinking from the recollection-level to the recognition-level.

The description of how a scientist would solve the problem of finding out whether materials really need oxygen from the air in order to burn is a good example of scientific procedure. The class, however, suggested a similar procedure during the discussion and the experiment meant more to them because it was performed to test their theory. Reading the account in the text would not have been as satisfying as a method of helping them reach a conclusion.

The experiment of burning the candle is described in the text so that the class may observe what happens. Faced with the problem of why a candle disappears, the group is alert to note any different substances that may be formed as the candle burns. The text gives a ready-made answer to this problem and eliminates the necessity of even watching the experiment.

As an answer to the question, "How can we put out a fire?" three methods are listed in the book. Illustrations of these three methods are given. There is a statement of why water puts out a fire and why it should not be used to extinguish a gasoline or kerosene fire. The carbon tetrachloride
and the carbon dioxide fire-extinguishers are described.

In class presentation the children are led to question the statement that water is the best fire-extinguisher by deciding how to put out a grease fire. The necessity for several types of fire-extinguishers and the principle on which they work is then seen in relation to the problem.

Instead of learning a set list of rules for fire prevention, the rules develop out of the discussion. After the data have been collected and evaluated, the conclusions are reached.

The comparisons that have been made between the text and the classroom presentation show quite definitely why this unit is not a good reflective study of fire control even though it improves the textbook method. In the first place, there was no genuine problem to be solved. The textbook problem was used with a few variations in presentation. There was an attempt to have the conclusions come at the close of the study but the problems were of the right-answer type.

This unit was taught toward the end of the school year when it is always difficult to do effective teaching. Periods are interrupted; pupils and teachers have a hurried feeling; there is an attempt to teach blocks of material or to plan units that will be completed in a set number of periods. A really reflective study of any problem cannot be developed under these circumstances.
The problem of how to control fires, although of general interest, is not quite broad enough to be the basis of a teaching unit. If it had been developed as a part of the unit on chemical change, just as many principles probably could have been developed in fewer days. The unit repeats material that was covered in the preceding unit. Dividing a large problem into several smaller problems in order to deal with them more extensively is often a waste of time that could better be spent in studying real problems.

There was no issue involved in the study of this problem. If the class had been confused by an attempt to put out a fire with water and seeing that it blazed more brightly, they might have been challenged to find out "why water burns." From this interest, the other principles probably could have been developed. This trick is described in any magician's book.

By suggesting and testing several theories as to why water failed to put out this fire, the class could have found out what is necessary for a fire and how fire can be controlled. Other problems that developed, such as types of fire extinguishers, role of oxygen in combustion, and the products of burning, would be related to the initial problem.
CHAPTER IV

EVALUATION OF THE STUDY

THE UNITS

The material in the three units presented in this study has been organized on the problem basis. Each unit presents a group of problems whose solution leads to the formulation of scientific principles and generalizations essential to the understanding of that aspect of the environment with which the unit is concerned. Broad concepts cannot be taught to children as such, but must be achieved through a very large number of well-planned, challenging experiences. By employing the problem method of attack, the units attempt to lead the children inductively toward development of meaning and the development of better methods of thinking.

A comparison of the three units shows significant differences in the methods of presentation and the results achieved. The first unit on electricity promotes more reflection-level thinking than do the others. There is a more challenging situation; the experiments and activities are

more worthwhile. The children collect information about electricity and use it to solve such problems as: "Why does a bell ring?" "How is electricity brought to our homes?" "How does a telephone work?" Of course, some of the problems were on the recognition-level of thinking and much of the information was not used. But, as a whole, the unit is adequate as a reflective study of electricity.

In contrast, the following unit on chemistry is rather formal. It is well-planned to bring out problems, but it sets up artificial situations. The children enjoyed the experiments, but there was neither the eagerness nor the enthusiasm that came from the preceding study. The problems were not the children's problems. The study follows the general pattern of effective thinking and the scientific method is employed in solving the problems, but the thinking tends to stay at the recognition-level. The children formulate their conclusions but they are not particularly concerned about them. There is no real feeling of discovery in the solutions of the problems.

The subject matter of the second unit is better organized than that of the first one. Perhaps it is too well-planned, and, for this reason, does not stimulate the children to independent thinking. In trying to make a unit follow a certain pattern, a teacher may become autocratic, even though the pattern attempts to set up a democratic situation.
Discussions should be guided, but they should not be dictated. The by-path a class chooses to follow may lead to just as important a destination as the marked route does.

Many teachers avoid the problem method of teaching because it is much easier to let a class do just what it wants to do, or to teach set facts and principles, than to guide the children in reaching their own conclusions. It is hardly conceivable that all pupils should emerge from school with the same set of conclusions, since they come with all kinds of backgrounds. Uniformity of conclusions is no more the goal of democratic teaching than is the absence of any conclusions.\(^1\)

As a reflective study, the third unit on fire control is the weakest of the series. It is neither planned nor executed on an effective problem-solving basis. Meanings are developed through right-answer questions instead of through conflicts, as in the preceding units. The unit follows the plan used in the textbook, except that the teacher attempts to have the children state the conclusions. In a group where there are a number of bright children, it is inevitable that many times right answers will be given almost immediately if the questions are not thought-provoking. The teacher often has to challenge these right answers to

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keep the class from placidly accepting them.\footnote{1} If a statement has further implications, it should be challenged, so that, through thinking, these implications will be developed. Most people are too willing to accept the opinions of others.

RESULTS

Learnings acquired

This study is conspicuous for its lack of statistical data concerning the scholastic achievements of the pupils. The units were taught in a system where numerical or letter grades are not given. Student progress is judged on the basis of attitude and industry rather than on ability to recall facts. Most of the information about the progress of pupils is subjective rather than objective. Tests are given, but teacher judgment, rather than test results, is the basis for promotion.

Previous to these units, the classes in science had been tested by summarizing activities over the unit, or by objective tests. The tests that were given at the close of each of the three units are not included in the discussions of the units. The test over the unit on electricity consisted of a number of questions about an electric bell

connected to a dry cell. It was a test of the pupil's ability to apply, in a practical situation, the facts and principles which had been discussed. The results were only fair. Several of the group could do nothing with the questions. Pupils, who have become accustomed to memorizing facts for a test, have to learn how to take a thought test. Ruth Mary, Dick, and Howard, who were the outstanding pupils in the group, did exceptionally well on this type of test. They were the most independent thinkers in the group.

At the close of the school year, the Stanford Achievement Test was given to all of the pupils. All of the science classes ranked high on the science test, but the class using this study showed more progress than any of the others. This group, consisting of thirty-three members, took the test in the eighth month of the sixth grade, so their standard grade median was 6-8. The class median, on the science section, was 8-2. Twenty-six children ranked above the standard median; two were in the ninth-grade group. The children who fell below the standard median were the same children who were unable to solve the thought problems in the test over electricity.

These results indicate that this group was advanced one year and three months in their knowledge of science as measured by this test. The other sixth-grade class had a median of 7-6; the fifth-grade had a class median of 6-4;
the fourth grade averaged 5-8. The validity of this test may be questioned, but it does give a basis for comparing the progress of classes.

Although memorization of facts is not stressed in these units, the children evidently acquired a great deal of science information. Emphasis was placed on finding data, rather than on learning them. When concepts are acquired through thinking, the data which help to develop these meanings become significant and are remembered. The data may then be used to solve other problems.

Attitudes established

The real value of the method used in teaching these units, however, lies not in the information accumulated by the children but in establishing patterns of effective thinking. Habits of thinking and attitudes are somewhat intangible qualities that are difficult to evaluate. Pupil comments, teacher opinion, and observations of parents are about the only ways of measuring growth in these qualities.

In observing the behavior of different individuals during the progress of the units, several comments can be made. There were at least five pupils in the group who never made a voluntary contribution to any of the discussions. They were neither interested in, nor challenged by, the problems. The method could not modify their behavior because they did no real thinking. Several of the group were rather
bored when an obviously correct answer was challenged. If something is right, why bother about it?

In contrast to the pupils who were unwilling to think either from inability or from laziness, most of the group were eager to take part in the discussions. They did not hesitate to recite because they might not know the answer. This technique of teaching encouraged the expression of opinions without immediate concern as to whether they were right or wrong. A wrong statement is often of more value than a right one in stimulating thought. The children soon realized that both right and wrong answers contributed to final conclusions.

The general attitude of the class was especially fine during the unit on electricity. The class was doing, and thinking about their doing. There was quite a difference between their attitude during this unit and during the third unit. The children were not especially interested in fire control. They had already discussed it in the preceding unit on chemical changes. The discussions did not start with any feeling of inadequacy in knowledge of how to put out a fire. Questions as what to do in case of a fire were answered immediately by the brighter members of the group. One might say this was because fire control is intrinsically less interesting to pupils than electricity. We do not believe so. Part of the restlessness and inattention of the class was due,
no doubt, to the season of the year, but the ineffectiveness of the unit as organized was also a contributing factor.

There is some evidence that the habits of thinking carried over into other subjects. In social studies, the children began to look for several sources of material to answer their problems rather than to be content with reading one book. They began to question the truth of some of the statements in their history and geography books. They suddenly realized that newspapers and the radio often make statements that are not accurate. Disbelief in magical things and in superstitions also was noticed. Children who have been doing independent thinking are not docile members of a group, ready to believe everything they hear and see.

A question might be raised: Are children out of control when they question the policies of a teacher or of the administration of a school? Unfortunately, many teachers resent having their statements challenged and the calm atmosphere of the schoolroom "unsettled" by unorthodox opinions.

Elementary pupils, who are alert to things going on about them and curious about many things, who ask questions, challenge statements, wish to try out things for themselves, demand evidence and reasons, check exaggerations, distinguish between the true and the "make-believe" in stories, are pupils who have a tendency to collect the evidence on both sides of a question before deciding, are open-minded and able
to change opinions; but they are not too easily swayed by their associates. Children with these healthy attitudes are going to grow up to be the type of citizen democracy demands.

SUMMARY

The description of the three science units, "Electricity," "Elementary Chemistry," and "Fire Control," is presented as an accurate account of actual teaching procedure in an elementary classroom. The analyses of the units indicate to what degree they were successful in promoting reflection-level thinking. Suggestions for improving the methods used are given in the hope that they will lead the reader to see what might have proved more successful. The units are evaluated as to pupil achievement in scholarship and attitudes. The study indicates that the problem-solving method of organizing material, if successfully employed, is an effective means of increasing a pupil's knowledge of his world and securing better methods of thinking.


McGraw Hill. 1937.


